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STANDARD WIRING
FOR
ELECTRIC LIGHT AND POWER

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STANDARD WIRING

FOR

ELECTRIC LIGHT AND POWER

AS ADOPTED BY

THE FIRE UNDERWRITERS

OF THE UNITED STATES

CONTAINING THE NATIONAL ELECTRICAL CODE EXPLAINED AND ILLUSTRATED, TOGETHER WITH THE NECESSARY TABLES AND FORMULÆ FOR OUTSIDE AND INSIDE WIRING AND CONSTRUCTION FOR ALL SYSTEMS

H. C. CUSHING, JR.

MEMBER AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS, LATE ELECTRICAL INSPECTOR BOSTON BOARD OF FIRE UNDERWRITERS AND NEW YORK FIRE UNDERWRITERS' TARIFF ASSOCIATION

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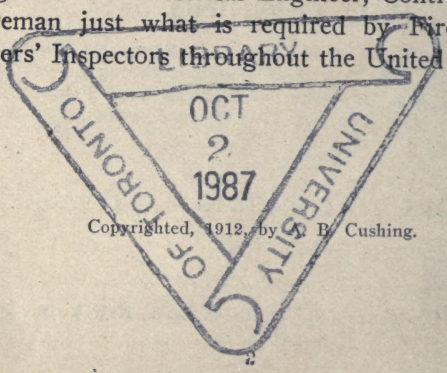
PREFACE.

THE author has, with the collaboration of Mr. F. E. Cabot, chairman of the Electrical Committee of the National Fire Protection Association and Mr. George T. Hanchett, S.B., Consulting Electrical and Mechanical Engineer, made it his aim in compiling the following pages to set forth, and explain, as clearly as possible, the essential rules and requirements for safe and economical exterior and interior electric light and power wiring and construction with an effort to standardize, as much as possible, all work of this nature, and to respectfully suggest to the Electrical Engineer, Contractor and Wireman just what is required by Fire Underwriters' Inspectors throughout the United States.



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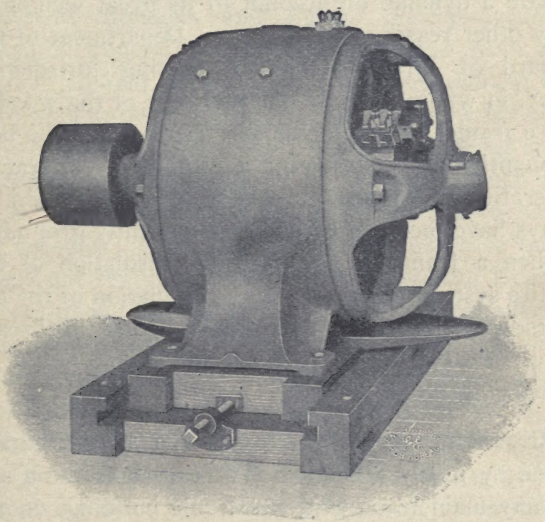
THE DYNAMO

All Dynamos, whether for central station or isolated lighting or power work, should be located in a dry place so situated that the surrounding atmosphere is cool. If the surrounding air is warm it reduces the safe carrying capacity of the machine,



Proper installation of dynamo or motor on filled wooden base frame.

and is likely to allow such temperatures to rise in the machine itself as to burn out either armature or field, or both. A dynamo should not be installed in any place where any hazardous process is carried on, nor in places where they would be exposed to inflammable gases or flying combustible materials, as the liability of occasional sparks from the commuta-

tor or brushes might cause more or less serious explosions.

Foundations. Wherever it is possible, dynamos should be raised or insulated above the surrounding floor on wooden base frames, which should be kept filled to prevent the absorption of moisture, and also kept clean and dry. When it is impracticable to insulate a dynamo on account of its great weight or any other reason, the Inspection Department of the Board of Fire Underwriters having jurisdiction may, in writing, permit the omission of the wooden base frame, in which case the frame should be permanently and effectively grounded. Generators operating at a potential of over 550 volts should always have their base frames permanently grounded. When a frame is grounded the insulation of the entire system depends upon the insulation of the dynamo conductors from the frame, and if this breaks down the system is grounded and should be put in proper condition at once.

Grounding Dynamo Frames can be effectually done by firmly attaching a wire to the frame and to any main water pipe inside the building, on the street side of the meter, if there is one. The wire should be securely fastened to the pipe by screwing a brass plug into the pipe and soldering the wire to this plug or by approved ground clamps. When the dynamo is direct driven an excellent ground is attained through the engine coupling and piping.

Wherever high potential machines have their frames grounded a small board walk should be built around them and raised above the floor on

porcelain or glass insulators, in order that the dynamo tender may be protected from a shock when adjusting brushes or working about the machine.

Accessibility. Sufficient space should be left on all sides of the dynamo, and especially at the commutator end, so that there may be ample room for removing armatures, commutators, or other parts at any time.

Circuit Breakers and Fuses. Every constant potential generator should be protected from excessive current by a safety fuse, or equivalent device of approved design, such as a circuit breaker. The latter is preferable on account of its being more accurate and convenient for resetting. Such devices should be placed on or as near the dynamo as possible. When the needs of the service make these devices impracticable, the Inspection Department having jurisdiction may, in writing, modify the requirements.

For two-wire, direct-current generators, single pole protection will be considered as satisfying the above rule, provided the safety device is located in the lead not connected to the series winding. When supplying three-wire systems, the generators should be so arranged that these protective devices will come in the outside leads.

For three-wire, direct-current generators, a safety device should be placed in each armature, direct-current lead, or a double pole, double trip circuit breaker in each outside generator lead and corresponding equalizer connection.

In general, generators should preferably have no exposed live parts and the leads should be well insu-

lated and thoroughly protected against mechanical injury. This protection of the bare live parts against accidental contact would apply also to all exposed, uninsulated conductors outside of the generator and not on the switchboard unless their potential is practically that of the ground.

Where the needs of the service make the above requirements impracticable, the Inspection Department having jurisdiction may, in writing, modify them.

Waterproof Covers, though not required, should be provided for every dynamo and placed over each machine as soon as it is shut down. Negligence in this matter has caused many an armature and field coil to burn out, as only a few drops of water are necessary to cause a short circuit, when the machine is started up again, that might do many dollars' worth of damage, to say nothing of the inconvenience of having to shut off light or power when it is most needed, and for an indefinite length of time.

Name Plates. Every dynamo should be provided with a name plate, giving the maker's name, the capacity in volts and amperes and normal speed in revolutions per minute. This will show exactly what the machine was designed for, and how it should be run.

Terminal blocks when used on generators should be made of *approved* non-combustible, non-absorptive, insulating material, such as slate, marble or porcelain.

Wiring from Dynamos to switchboards and thence to outside lines should be in plain sight or readily accessible, and should be supported entirely

throughout upon non-combustible insulators (such as glass or porcelain, in no case should any wire come in contact with anything except these insulators, and the terminals upon the dynamos and switchboard. When it becomes necessary to run these wires through a wall or floor, the holes must be protected by some approved non-combustible insulating tube, such as glass or porcelain, and in every case the tube must be so fastened that it shall not slip or pull out. Sections of any tubing, whether armored or otherwise, that are chopped off for this purpose, should not be used. All wires for dynamos and switchboard work should be kept so far apart that there is no liability of their coming in contact with one another, nor of short circuit from metallic tools used about them, and should be covered with non-inflammable insulating material of a thickness equivalent to that of "slow burning" wire, see page 65, and having a smooth, hard outer surface, except that bus bars may be made of bare metal, so that additional circuits may be readily attached. They must have ample carrying capacity, so as not to heat with the maximum current likely to flow through them under natural conditions. (See "Capacity of Wire Table," page 74.) So much trouble in past years has arisen from faulty construction of switchboards, and the apparatus placed upon them, that strict requirements have been necessarily adopted by engineers as well as insurance inspectors, and the following suggestions are recommended by the latter; although it is advisable, when possible, that all wires from generators to switchboards be in plain sight and readily accessible.

Wires from generator to switchboard may, however, be placed in a conduit in the brick or cement pier on which the generator stands, provided that proper precautions are taken to protect them against moisture and to thoroughly insulate them from the pier. If lead-covered cable is used, no further protection will be required, but it should not be allowed to rest upon sharp edges which in time might cut into the lead sheath, especially if the cables were liable to vibration. A smooth runway is desired. If iron conduit is provided, double braided rubber-covered wire will be satisfactory.

The Switchboard should be so placed as to reduce to a minimum the danger of communicating fire to adjacent combustible material, and, like the dynamo, should be erected in a dry place and kept free from moisture. It is necessary that it should be accessible from all sides when the wiring is done on the back of the board, but may be placed against a brick or stone wall when all wiring is on the face of the switchboard.

The board should be constructed wholly of non-combustible material, but when this is impossible a hard wood board made in skeleton form and well filled, to prevent absorption or moisture, is considered safe. Every instrument, switch or apparatus of any kind placed upon the switchboard should have its own non-combustible insulating base. This is required of every piece of apparatus connected in any way with any circuit. If it is found impossible to place the resistance box or regulator, which should, in every case, be made entirely of non-combustible material, upon the switchboard, it must be

placed at least one foot from combustible material or separated therefrom by a non-inflammable, non-absorptive insulating material. This will require the use of a slab or panel of non-combustible, non-absorptive insulating material such as slate or marble, somewhat larger than the rheostat, which shall be secured in position independently of the rheostat supports. Bolts for supporting the rheostat shall be countersunk at least ⅛ inch below the surface at the back of the slab and the holes over the heads of the bolts filled. For proper mechanical strength, the slab should be of a thickness consistent with the size and weight of the rheostat, and in no case to be less than ½ inch.

If resistance devices are installed in rooms where dust or combustible flyings would be liable to accumulate on them, they should be equipped with a dust-proof face plate. Where protective resistances are necessary in connection with automatic rheostats, incandescent lamps may be used, provided that they do not carry or control the main current nor constitute the regulating resistance of the device.

When so used, lamps should be mounted in porcelain receptacles upon non-combustible supports, and should be so arranged that they cannot have impressed upon them a voltage greater than that for which they are rated. They should in all cases be provided with a name-plate, which shall be permanently attached beside the porcelain receptacle or receptacles and stamped with the candle-power and voltage of the lamp or lamps to be used in each receptacle.

Wherever insulated wire is used for connection

between resistances and the contact plate of a rheostat, the insulation should be "slow burning." For large field rheostats and similar resistances, where the contact plates are not mounted upon them, the connecting wires may be run together in groups so arranged that the maximum difference of potential between any two wires in a group should not exceed 75 volts. Each group of wires should either be mounted on non-combustible, non-absorptive insulators giving at least ½ inch separation from surface wired over, or, where it is necessary to protect the wires from mechanical injury or moisture, be run in *approved* lined conduit or equivalent. Special attention is called to the fact that switchboards should not be built down to the floor, nor up to the ceiling, but a space of at least ten or twelve inches should be left between the floor and the board, and from twenty-four to thirty-six inches between the ceiling and the board, when possible, in order to prevent fire from communicating from the switchboard to the ceiling, and also to prevent the forming of a partially concealed space very liable to be used for storage of rubbish and oily waste. Where floor is of brick, stone or concrete, the switchboard may go to the floor. For the protection of instruments and pilot lights on switchboards, *approved* N. E. Code Standard Enclosed Fuses are recommended.

Lightning Arresters should be attached to each side of every overhead circuit connected with the station.

It is recommended to all electric light and power companies that arresters be connected at intervals over systems in such numbers and so located as to

prevent ordinary discharges entering (over the wires) buildings connected to the lines.

Arresters for Stations and Sub-stations should be located in readily accessible places away from combustible materials, and as near as practicable to the point where the wires enter the building.

Station arresters are often placed in plain sight on the switchboard. The switchboard, however, does not necessarily afford the only location meeting these requirements. In fact, if the arresters can be located in a safe and accessible place away from the board, this should be done, for, in case the arrester should fail or be seriously damaged there would then be less chance of starting arcs on the board.

In all cases, kinks, coils and sharp bends in the wires between the arresters and the outdoor lines should be avoided as far as possible.

They should be connected with a thoroughly good and permanent ground connection by metallic strips or wires having a conductivity not less than that of a No. 6 B. & S. copper wire, and these should be run as nearly in a straight line as possible from the arresters to the earth connection.

Ground wires for lightning arresters should not be attached to gas-pipes within the buildings.

It is often desirable to introduce a choke coil in circuit between the arresters and the dynamo. In no case should the ground wire from a lightning arrester be put into iron pipes, as these would tend to impede the discharge.

Unless a good damp ground is used in connection with all lightning arresters, they are little better

than useless. Ground connections should be of the most approved construction, and should be made where permanently damp earth can be conveniently reached. For a bank of arresters such as is commonly found in a power house, the following instructions will be found valuable: First, dig a hole six feet square directly under the arresters until permanently damp earth has been reached; second, cover the bottom of this hole with two feet of crushed coke or charcoal (about pea-size); third, over this lay 25 square feet of No. 16 copper plate; fourth, solder at least two ground wires, which should not be smaller than No. 4, securely across the entire surface of the ground plate; fifth, now cover the ground plate with two feet of crushed coke or charcoal; sixth, fill in the hole with earth, using running water to settle.

A practical and effective method of installing an outside line arrester is shown on page 48.

All lightning arresters should be mounted on noncombustible bases, and be so constructed as not to maintain an arc after the discharge has passed.

Testing of Insulation Resistance. All circuits except such as are permanently grounded, as described on pages 44 and 45, should be provided with reliable ground detectors. Detectors which indicate continuously and give an instant and permanent indication of a ground are preferable. Ground wires from detectors should not be attached to gas pipes within the building.

Where continuously indicating detectors are not feasible, the circuits should be tested at least once per day (see page 63), and preferably oftener.

Data obtained from all tests should be preserved for examination.

Storage or Secondary Batteries should be installed with as much care as dynamos, and in wiring to and from them the same precautions and rules should be adopted for safety and the prevention of leaks. The room in which they are placed should not only be kept dry, but exceptionally well ventilated, to carry off all fumes which are bound to arise. The insulators for the support of the secondary batteries should be glass or porcelain, as filled wood alone would not be approved. The use of any metal liable to corrosion should be avoided in cell connections of secondary batteries.

Care of Dynamos. A few suggestions as to the care of the dynamo, as well as its installation, may be of value, and one of the important points under that head is that the driving power should have characteristics of steadiness and regularity of speed, and should always be sufficient to drive the dynamo with its full load, in addition to the other work which it may be called upon to sustain. Unsatisfactory results are always obtained if attempting to run a dynamo on an overloaded engine.

Wooden bed plates are supplied, when ordered, for all dynamos, except in the largest and direct-connected machines.

Most machines are fitted with a ratchet and screw bolt, so that they may be moved backward or forward on the bed plate in a direction at right angles to the armature shaft. By this means the driving belt may be tightened or loosened at will while the machine is in operation. Care should be taken in

tightening the belt not to bind the bearings of the armature and force the oil from between the surface of the shaft and boxes. Such practice will inevitably cause heating of the bearings and consequent injury.

Machines are usually assembled, unless ordered otherwise, so that the armature revolves from left to right when the observer faces the pulley end of the shaft. All bipolar dynamos, however, may be driven in either direction by reversing the brushes and changing field connections.

The machine, if belt driven, is provided with a pulley of the proper size to produce the proper speed, and one of different size should not be substituted unless approval be obtained from the dynamo makers.

When driving from a countershaft, or when belted directly to the main shaft, a loose pulley or belt holder should be used, to admit of starting and stopping the dynamo while the shafting is running.

Belts. A thin double or heavy single belt should be used, about a half-inch narrower than the face of the pulley on the dynamo. An endless belt, one without lacing, gives the greatest steadiness to the lights. For proper length of belts see formula on page 131.

All Bolts and nuts should be firmly screwed down. All nuts which form part of electrical connections should receive special attention.

When copper commutator brushes are used they are carefully ground to fit the commutator, and they should be set in the holders so as to bear evenly upon its surface.

On machines where two or more brushes are sup-

ported on one spindle, the brushes on the same side of the commutator must be set so that they touch the same segments in the same manner. The brushes on the other side of the commutator must be set so as to bear on the segments diametrically opposite. When the brushes are not so set it is impossible to run the machine without sparking. A convenient method of determining the proper bearing point for the brushes is to set the toe of one brush at the line of insulation, dividing two segments to the commutator; then count the dividing lines for one-half the way around the surface, and set the other brush or brushes at the line diametrically opposite the first. Thus, on a forty-four segment commutator, after setting the tip of one brush at a line of insulation, count around twenty-three lines, setting the other brush at the twenty-third line, thus bringing the tips directly opposite each other. The angle which the brushes form with the surface of the commutator should be carefully noted, and the brushes should not be allowed to wear, so as to increase or decrease this angle. Careless handling of the machine is at once indicated by the brushes being worn either to a nearly square end or to a long taper, in which the forward wires of the brush far outrun the back or inside wires. Either condition cannot fail to be attended with excessive wear of both commutator and brushes.

After copper brushes are set in contact with the commutator, the armature should never be rotated backward. If it is required to turn the armature back, raise the brushes from the commutator by the thumb screw on the holder provided for that pur-

pose, before allowing such rotation. When starting a machine, it is always better to let the brushes down upon the commutator after the machine has started rather than before, except when carbon brushes are used, which are now almost universal.

Bearings. See that the bearings of the machine are clean and free from grit, and that the oil reservoirs are filled with a good quality of lubricating oil.

The Oil Reservoirs should always be examined before starting, and all loose grit removed. After starting the machine, the oil should all be drawn off at the end of each day's run for the first three or four days, after which it can be assumed that any remaining grit has been carried off with the oil, and it will only be necessary to add a little fresh oil once in seven to ten days.

In starting up a dynamo or motor fill the oil reservoirs and see that the automatic oiling rings are free to move. In the case of dynamos fitted with oil cups, start the oil running at a moderate rate. Too little oil will result in heating and injury of the bearing; but, on the other hand, excessive lubrication is unnecessary, wasteful, and sometimes productive of harm.

When the dynamo is ready to be started, place the driving belt on the pulley on the armature shaft, and then slip it from the loose pulley or belt holder on to the driving pulley on the counter-shaft. Tighten the belt, by means of the ratchet on the bed plate, just sufficiently to keep it from slipping. Care should be taken not to put more pressure than is necessary on bearings; carelessness in this respect is often followed by heat-

ing of the boxes, and possible permanent injury.

The brushes may now be let down upon the commutator, and the magnets will be slowly energized.

Move the brushes slowly backward or forward by means of the yoke handle, until there is no sparking at the lower brushes. Clamp the yoke in this position. If the top brushes then spark, move them slightly, one at a time, forward or backward in the brush holder until their non-sparking point is found.

The spring pressure exerted upon the commutator brushes should be just sufficient to produce a good contact without causing cutting. If the brushes cut, the commutator must be smoothed by the use of fine sandpaper, NOT emery cloth.

The dynamo should run, without load, at the speed given by the manufacturer, and this speed should be uniformly maintained under all conditions. In the case of dynamos for incandescent lighting, any increase of speed, above that given, is prejudicial to the life of the lamps, while a variation below causes unsatisfactory lights.

Before starting, a D. C. dynamo should be tested for polarity. This may be done by holding a small pocket compass near the field or pole piece. If the dynamo is connected to be run in multiple with another machine and happens to be polarized wrong, it can be given the right polarity by lifting the brushes from the commutator, closing the field switch, and then closing the double-pole switch used to throw it in multiple with the other machine, which is supposed to be now running. After the current has been allowed to pass through the fields

for a few moments, the double-pole switch can be thrown open, and if a test with the compass is again made the polarity will be found to be right, and the dynamo is ready to be started in the usual manner.

If the dynamo is to be used in series with another on the three-wire system, and is found to be polarized wrong, it can be given the right polarity by making a temporary connection from the positive brush of the new machine to the positive brush of the machine already in operation; and also a temporary connection from negative brush to negative brush, having first raised the brushes from the commutator and closing the field switch. Keep this connection for a few minutes, then open the field switch and break the temporary connections.

Another test with the compass will show that the polarity of the machine is now correct, and the dynamo is ready to be started in the usual manner.

Assuming that the lamps and lines are all ready, the following precautions must be observed when starting the dynamo:

Be very careful that the brushes are properly set and diametrically opposite each other, as explained before.

Be sure that all connections are securely made, and all nuts on the connection boards firmly set

In cases where two or more dynamos are connected in multiple by the use of the equalizing connection, care should be taken that the circuit wires from both positive brushes be connected to the same side of the main line, while those from the negative are connected to the other side.

A neat arrangement of the equalizing connection can be made by using triple-pole switches on the switchboard, instead of double-pole switches, and making the equalizing connections through the center pole of the switch, instead of running a cable direct from one dynamo to the other. This method is especially desirable where three or more dynamos are run in multiple.

When dynamos are connected in series, as in the cases where the three-wire system is in use, the leading wire from the positive brush of one machine is connected to the negative brush of the other. The other two brushes (negative and positive) are connected to the main wire on the outside of the system, while the third or center wire is connected to the conductor between the two dynamos.

Keep all commutator and brush holder insulations free from dust, gritty substances and oil. They should be carefully cleaned once a day.

If any of the connections of the machine become heated, examination will show that the metal surfaces are not clean or not in perfect contact. Avoid the use of water or ice on the bearing in case of accidental heating, as the water may get to the armature and injure the insulation.

The Commutator should be kept clean and allowed to polish or glaze itself while running. No oil is necessary unless the brushes cut, and then only at the point of cutting. A cloth slightly greased with vaseline is best for the purpose. Never use sandpaper on the commutator without first lifting the brushes. Otherwise, the grit will

stick to the brushes and cut the commutator.

Brushes. Care should be taken to keep copper commutator brushes in good shape, and not to allow them to be worn out of square; that is, too much to one side, so that the end is not worn at right angles to the lateral edges.

When the machine is not running, the brushes should always be raised from the commutator.

The brushes should be kept carefully cleaned, and no oil or dirt allowed to accumulate upon them. This can be done by washing them occasionally in benzine or a hot solution of soda ash.

Manufacturers usually furnish a gauge, which should be used occasionally to test the wearing of the brushes. If they are found to be worn either too flatly or too bluntly, they should be filed in proper shape, or, better still, ground on a grindstone. Carbon brushes require less care.

Spindles upon which the brush holders are arranged to slide should be cleaned with emery cloth often enough to prevent tarnishing or the collection of dirt, which might cause heating by impairing the electrical connection.

Brush Holders which can be moved laterally on the spindle by which they are supported, should be so arranged that the top and bottom brushes will bear on different parts of the length of the commutator, for the purpose of distributing the wear more uniformly.

In case of a hot box the most natural thing to do is to shut the machine down, but this should never be done until the following alternatives have been tried and have failed:

First—Lighten the load.

Second—Slacken the belt.

Third—Loosen the caps on the boxes a little.

Fourth—Put more oil in bearings.

Fifth—If all the above fail to remedy the heating, use a heavy lubricant, such as vaseline or cylinder oil. Should the heating then diminish, the shaft must be polished with crocus cloth and the boxes scraped at the end of the day.

Sixth—Under no conditions put ice upon the bearing, unless you are perfectly familiar with such a procedure.

Seventh—If it is absolutely necessary to shut down, get the belt off as soon as possible, keeping the machine revolving meanwhile in order to prevent sticking, and at the same time take off the caps of the bearings. Do not stop the flow of oil to the bearings. When the caps have been taken off, stop the machine and get the linings out immediately, and allow them to cool in the air. Do not throw the linings into cold water, as it would be apt to spring them.

Scraping should be done only by an experienced person, otherwise the linings may be ruined. Polish the shaft with crocus cloth, or, if badly cut, file with a very fine file, and afterward polish with crocus. Wipe the shaft, as well as the boxes, very carefully, as perhaps grit has been the cause of the hot box. Inspect the bearings, see that they are in line, that the shaft has not been sprung, and that the oil collar does not bear against the box.

Oily Waste should be kept in approved metal cans (made entirely of metal, with legs raising

them at least three inches above the floor, and with self-closing covers) and removed daily.

Care and Attendance. A competent man should always be kept on duty where generators are operating.

MOTORS.

The Installation of Motors. All motors for 550 volts or less, should be insulated on wooden floors or base frames, which should be kept filled to prevent absorption of moisture; and kept clean and dry. Where frame insulation is impracticable the Inspection Department having jurisdiction may, in writing, permit its omission, in which case the frame should be permanently and effectively grounded. The use of motors operating at a potential in excess of 550 volts will only be approved when every practicable safeguard has been provided. Plans for such installations should be submitted to the Inspection Department having jurisdiction before any work is begun.

A high-potential machine which, on account of great weight or for other reasons, cannot have its frame insulated, should have its frame permanently grounded and should be surrounded with an insulated platform. This may be made of wood, mounted on insulating supports, and so arranged that a man must stand upon it in order to touch any part of the machine. Motors operating at a potential of 550 volts or less should be wired with the same precautions as required for lighting wires carrying a current of the same volume.

Motors operating at a potential between 550 and 3,500 volts should be wired with approved multiple

conductor, metal sheathed cable in approved unlined metal conduit firmly secured in place. The metal sheath should be permanently and effectively grounded, and the construction and installation of the conduit should conform to rules for interior conduits, except that at outlets approved outlet bushings should be used in place of the outlet box.

The leads or branch circuits should be designed to carry a current at least 25 per cent. greater than that required by the rated capacity of the motor to provide for the inevitable excess current used by the motor at times, especially when starting, without overfusing the wires. Where the wires would be overfused, in order to provide for the starting current, as in the case of many of the alternating current motors, the wires should be of such size as to be properly protected by these larger fuses.

The insulation of the several conductors for high potential motors, where leaving the metal sheath at outlets, should be thoroughly protected from moisture and mechanical injury. This may be accomplished by means of a pot head or some equivalent method. The conduit should be substantially bonded to the metal casings of all fittings and apparatus connected to the inside high tension circuit. It would be much preferable to make the conduit system continuous throughout by connecting the conduit to fittings and motors by means of screw joints, and this construction is strongly recommended wherever practicable.

High potential motors should preferably be so located that the amount of inside wiring will be reduced to a minimum.

Inspection Department having jurisdiction may permit the wire for high potential motors to be installed according to the general rules for high potential systems when the outside wires directly enter a motor room. Under these conditions there would generally be but a few feet of wire inside the building and none outside the motor room.

The motor and the rheostat should be protected by a cutout or circuit breaker, and controlled by a switch (see illustrations on pages 32 to 37), said switch plainly indicating whether "on" or "off." Where one-fourth horse-power or less is used on circuits where the voltage does not exceed 300, a single-pole switch will be accepted. The switch and rheostat should be located within sight of the motor, except in such cases where special permission to locate them elsewhere is given, in writing, by the Inspection Department having jurisdiction.

In connection with motors the use of circuit-breakers, automatic rheostats with automatic under-load switches is recommended, wherever it is possible to install them.

Where the circuit-breaking device on the motor-starting rheostat disconnects all wires of the circuit, the switch called for in this section may be omitted. Overload-release devices on motor-starting rheostats should not be considered to take the place of the cut-out required by this section if they are inoperative during the starting of the motor.

The switch is necessary for entirely disconnecting the motor when not in use, and the cut-out to protect the motor from excessive currents due to accidents or careless handling when starting. An auto-

matic circuit-breaker disconnecting all wires of the circuit may, however, serve as both switch and cut-out. The use of circuit-breakers with motors is recommended, and may be required by the Inspection Department having jurisdiction.

To be safe, a rheostat should have as great a carrying capacity as the motor itself, or else the arm should have a strong spring-throw attachment, so arranged that it cannot remain at any intermediate position unless purposely held there. See cut on page 27.

Starting rheostats and auto starters, unless equipped with tight casings enclosing all current-carrying parts, should be treated about the same as knife switches, and in all wet, dusty or linty places, should be enclosed in dust-tight, fireproof cabinets. If a special motor room is provided, the starting apparatus and safety devices should be included within it. Where there is any liability of short circuits across their exposed live parts being caused by accidental contacts, they should either be enclosed in cabinets, or else a railing should be erected around them to keep unauthorized persons away from their immediate vicinity.

Motors should not be run in series-multiple or multiple-series, except on constant-potential systems, and then only by special permission of the Inspection Department having jurisdiction.

Like generators, they should be covered with a waterproof cover when not in use, and, if necessary, should be inclosed in an approved case.

When it is necessary to locate a motor in the vicinity of combustibles or in wet or very dusty

or dirty places, it is generally advisable to enclose it in a dust-tight fireproof cabinet.

Such enclosures should be readily accessible and sufficiently ventilated to prevent an excessive rise of temperature. The sides should preferably be made largely of glass, so that the motor may be always plainly visible. This lessens the chance of its being neglected, and allows any derangement to be at once noticed.

The use of the enclosed type of motor is recommended in dusty places, being preferable to wooden boxing.

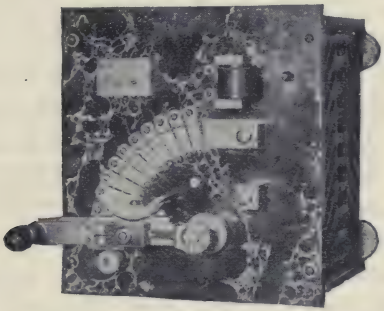
Motors, when combined with ceiling fans, should be hung from insulated hooks, or else there should be an insulator interposed between the motor and its support.

Every motor should be provided with a nameplate, giving the maker's name, the capacity in volts and amperes, and the normal speed in revolutions per minute.

Starting and Stopping Motors (Direct Current) One rule at all times to be remembered in starting and stopping motors is, *switch first, rheostat last,* which means, in starting, *close the switch first,* and then gradually cut out all resistance as the motor speeds up, and to stop the motor *open the switch first* and then cut in all the resistance of the rheostat which is in series with the motor armature. When starting any new motor for the first time, see that the belt is removed from the pulley and the motor started with no load. Never keep the rheostat handle on any of its coils longer than a moment, as they are not designed to regulate the

speed of the motor, but to prevent too large a flow of current into the armature before the latter has attained its full speed.

The illustration below shows a rheostat which is designed to automatically protect the armature of a motor. The contact arm is fitted with a spring which constantly tends to throw the arm on the "off-point" and open the circuit, but is prevented from so doing, while the motor is in operation, by the small electro-magnet, shown on the face of the



A Standard "Rheostat," "Resistance Box" or "Starting Box" for Motor, slate front, with iron top, bottom and sides ventilated.

rheostat, which consists of low resistance coil connected in series with the field winding of the motor. This magnet holds the contact arm of the rheostat in the position, allowing the maximum working current to flow through the armature while it is in operation.

If, for some reason or other, the current supplied to the motor be momentarily cut off, the speed of the armature generates a counter current which also tends to hold the arm in position as long as

there is any motion to the motor armature, but as soon as the armature ceases to revolve all current ceases to flow through the electromagnet, thereby releasing the rheostat handle, which flies back to the "off point," as shown in the illustration, and the motor armature is out of danger. Such a device is of great value where inexperienced men have to handle motors, and are unaware that the first thing to be done when a motor stops for any reason whatever is to open the circuit, and then cut in all the resistance in the rheostat to prevent too large an in-rush of current when the motor is started up again.

The Circuit Breaker for under and over loads is also a most valuable protection in such cases.

Motor Wiring Formulae—(Direct Current). To find the proper size of wire for direct-current motors proceed as follows:

e = potential of motor.

d = distance of generator to motor in feet.

v = volts loss in lines. k = efficiency of motor.

(See p. 29.)

10.8 = Resistance in ohms of a wire 1 ft. long and .001 inch diameter. Then

$$\text{circular mils} = \frac{\text{horse-power} \times 746 \times 2d \times 10.8}{e \times v \times k}$$

$$\text{or simplified cm} = \frac{\text{horsepower} \times d \times 16113.6}{e \times v \times k}$$

Compare the size of wire thus found with that allowed by the underwriters for full load current of motor, + 25%. If it be smaller it must be increased

to at least that figure to pass the authorities and the resulting lower line loss accepted.

THE AVERAGE MOTOR EFFICIENCY (K).

1 h.p.	75 per cent.
3 h.p.	80 per cent.
5 h.p.	85 per cent.
10 h.p. and over	90 per cent.

For Most Cases—(Small Installations). The tables and examples worked out on pages 51-53 and 66-69 will give the desired results, in many cases, without having to use the above formulæ.

To find current required by a motor when the horse-power, efficiency and voltage are known, use the following formula:

Let C = current to be found. H. P. = horse-power of motor.
E = voltage of motor circuit. K = efficiency of motor in per cent.

$$C = \frac{H.P. \times 746 \times 100}{E \times K}$$

The table of "amperes per motor" given on the following page, will prevent the trouble of working out the above formula in many cases.

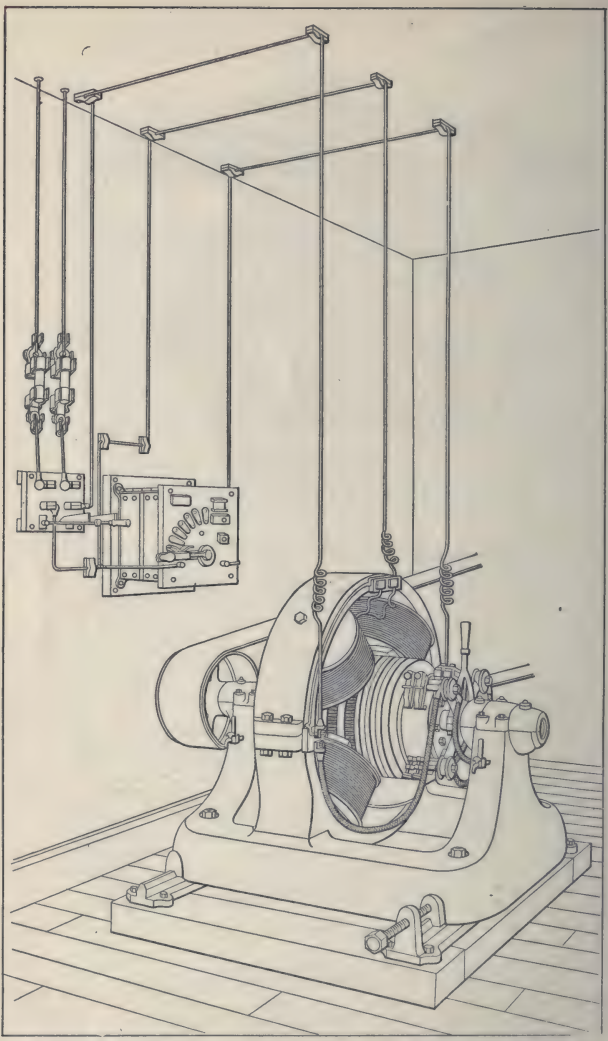
By adding the volts indicated in the following table to the voltage of the lamp or motor, the result shows the voltage at the dynamo for losses indicated. Thus, 10 per cent. on 110 volt system is: 12.22 volts added to 110 equal 122.22, showing that the dynamo must generate 122.22 volts for a 10 per cent. loss.

AMPERES PER MOTOR.

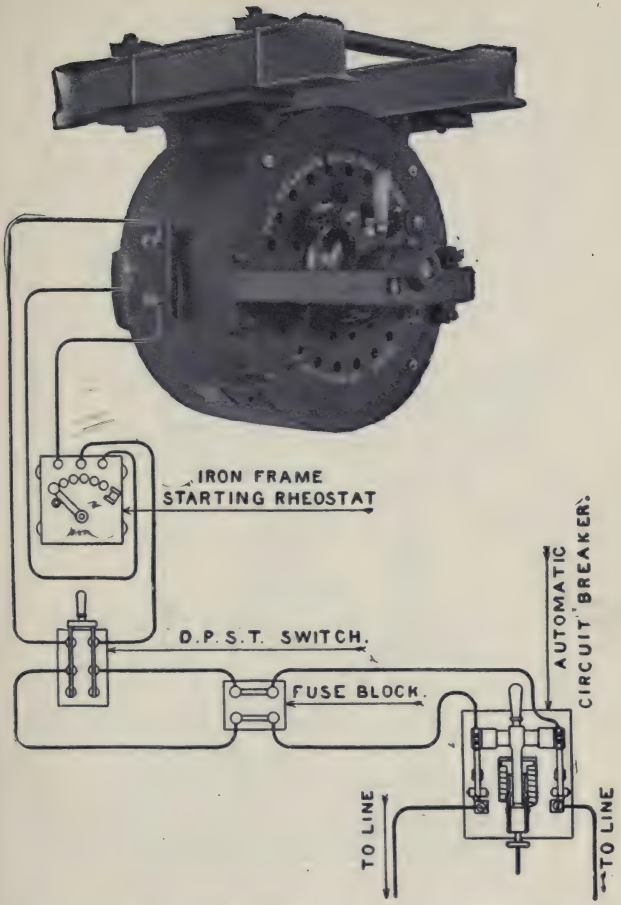
H. P.	Per Cent. Eff.	Watts.	The Top Row Indicates Volts.									
			50	75	110	220	400	500	600	800	1000	1200
¾	75	746	14.9	9.95	6.78	3.39	1.87	1.49	1.24	.93	.746	.62
1½	75	1492	29.8	19.9	13.56	6.78	3.73	2.98	2.49	1.87	1.492	1.24
3	80	2797	55.9	37.3	25.4	12.7	6.99	5.59	4.66	3.50	2.797	2.33
5	80	4662	93.2	62.2	42.4	21.2	11.74	9.32	7.77	5.83	4.662	3.88
7½	90	6217	124.	82.9	56.5	28.3	15.54	12.43	10.38	7.77	6.217	5.18
10	90	8288	166.	111.	75.3	37.7	20.72	16.57	13.81	10.36	8.288	6.91
15	90	12433	249.	166.	113.	56.5	31.08	24.86	20.72	15.54	12.43	10.36
20	90	16578	332.	221.	151.	75.5	41.45	33.15	27.63	20.72	16.58	13.81
25	90	20722	414.	276.	188.	94.1	51.8	41.4	34.5	25.9	20.7	17.3
30	90	24866	497.	331.	226.	113.	62.2	49.7	41.4	31.	24.9	20.7
40	90	33155	663.	442.	301.	151.	82.9	66.3	55.3	41.4	33.2	27.6
50	90	41444	829.	553.	377.	189.	101.	82.9	69.	51.8	41.4	34.5
60	90	49733	995.	663.	452.	226.	124.	99.5	82.9	62.	49.7	41.4
70	90	58022	1160.	773.	527.	264.	145.	116.	96.7	72.5	58.	48.4
80	90	66310	1326.	884.	603.	303.	166.	133.	111.	82.9	66.3	55.3
90	90	74599	1492.	995.	678.	339.	187.	149.	124.	93.	74.6	62.
100	90	82888	1658.	1105.	754.	377.	207.	166.	138.	104.	82.9	69.
120	90	99467	1989.	1326.	904.	452.	249.	199.	166.	124.	99.	82.9
150	90	124333	2487.	1658.	1130.	565.	311.	249.	207.	155.	124.	104.

VOLTS LOST AT DIFFERENT PER CENT. DROP.

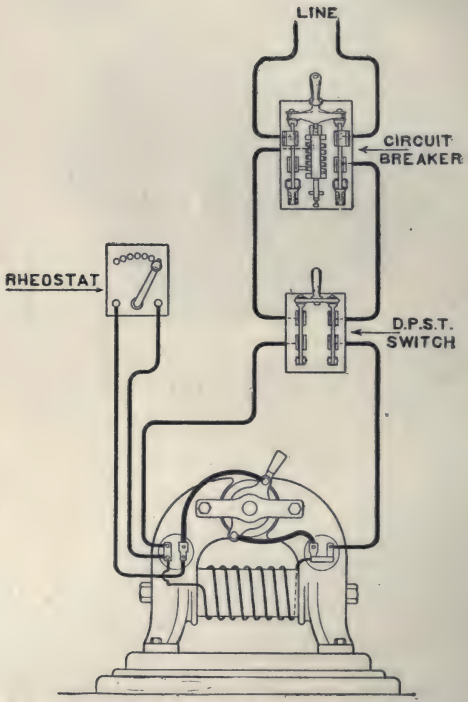
Termin'l Volts	52	104	110	120	240	550	1100	2200	6600	11000
%										
.5	.261	.523	.553	.603	1.21	2.76	5.53	11.06	33.17	55.28
1.	.525	1.05	1.11	1.21	2.42	5.56	11.11	22.22	66.67	111.11
1.5	.791	1.58	1.68	1.83	3.65	8.38	16.75	33.50	100.50	167.51
2.	1.06	2.12	2.24	2.45	4.90	11.22	22.45	44.90	132.65	224.48
2.5	1.33	2.67	2.82	3.08	6.15	14.10	28.21	56.41	169.23	282.05
3.	1.61	3.22	3.40	3.71	7.42	17.01	34.02	68.04	204.11	340.20
3.5	1.89	3.77	3.99	4.35	8.70	19.95	39.90	79.79	239.37	398.96
4.	2.17	4.33	4.58	5.00	10.00	22.92	45.83	91.67	275.00	458.33
5.	2.74	5.47	5.79	6.32	12.63	28.95	57.90	115.79	347.36	578.94
6.	3.32	6.70	7.02	7.66	15.32	35.11	70.21	140.42	421.27	702.12
7.	3.91	7.83	8.28	9.03	18.06	41.40	82.80	165.59	496.77	827.95
8.	4.52	9.04	9.57	10.43	20.87	47.83	95.65	191.30	573.90	956.52
9.	5.14	10.29	10.88	11.87	23.74	54.40	108.79	217.58	652.75	1087.91
10.	5.78	11.56	12.22	13.33	26.67	61.11	122.22	244.44	733.33	1222.21
11.	6.43	12.85	13.59	14.83	28.66	67.97	135.95	271.90	815.69	1359.49
12.	7.09	14.18	15.00	16.36	32.72	75.00	150.00	299.99	899.98	1499.96
13.	7.77	15.54	16.44	17.93	35.86	82.18	164.36	328.72	986.17	1643.62
14.	8.46	16.93	17.91	19.53	39.07	89.53	179.07	358.14	1074.41	1790.69
15.	9.17	18.35	19.41	21.18	42.35	97.06	194.12	388.23	1164.70	1941.17
20.	13.00	26.00	27.50	30.00	60.00	137.50	275.00	550.00	1650.00	2750.00
25.	17.33	34.67	36.67	40.00	80.00	183.33	366.66	733.33	2199.98	3666.63



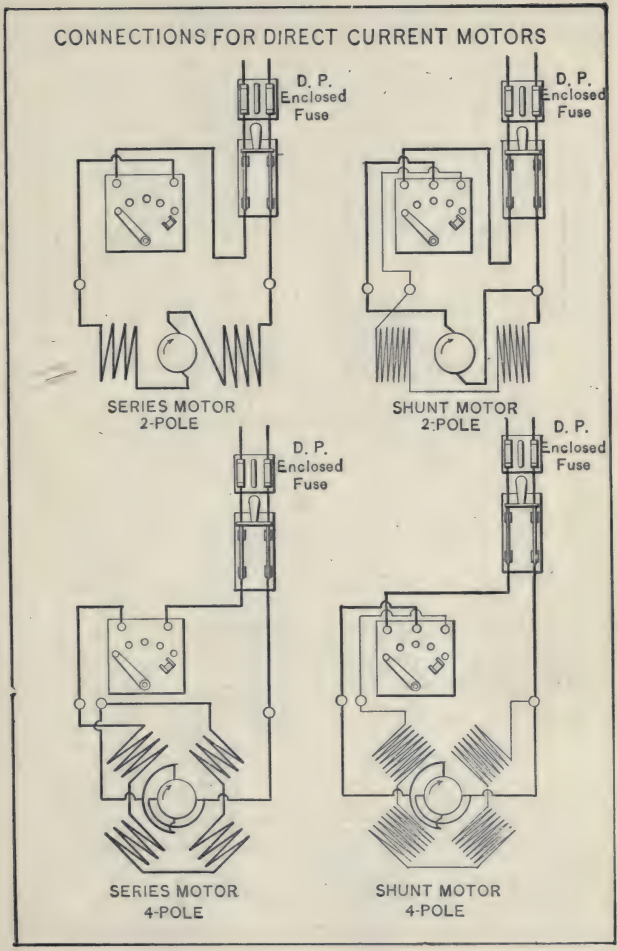
An approved installation in every detail, and wiring connections for shunt-wound, four-pole motor, using two enclosed fuses instead of circuit breaker.



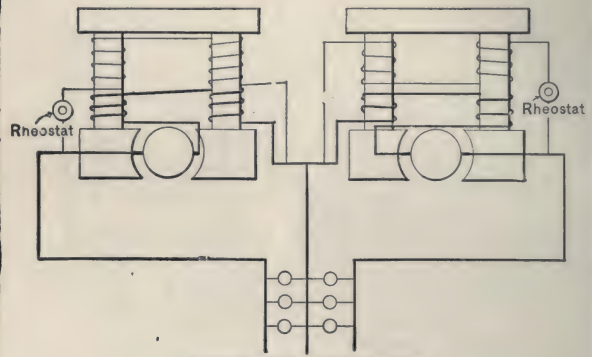
An approved installation in every detail and wiring connections for shunt-wound multipolar slow speed ceiling motor for direct connection to line shafting, using both circuit breaker and double-pole fuse cut-out.



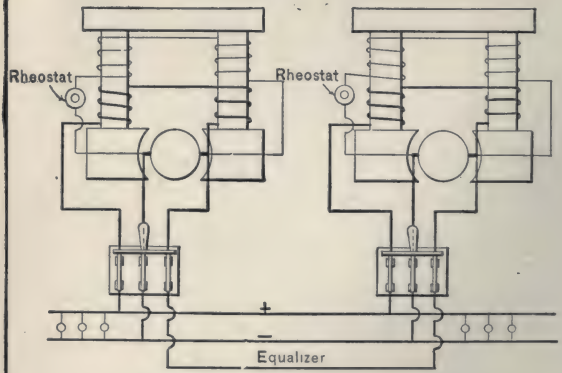
An approved installation in every detail, and wiring connections, for shunt-wound bipolar motor, using circuit breaker instead of double-pole fuse cut-out.


CONNECTIONS FOR DIRECT CURRENT MOTORS
D. P. Enclosed Fuse
SERIES MOTOR 2-POLE
D. P. Enclosed Fuse
SHUNT MOTOR 2-POLE
D. P. Enclosed Fuse
SERIES MOTOR 4-POLE
D. P. Enclosed Fuse
SHUNT MOTOR 4-POLE

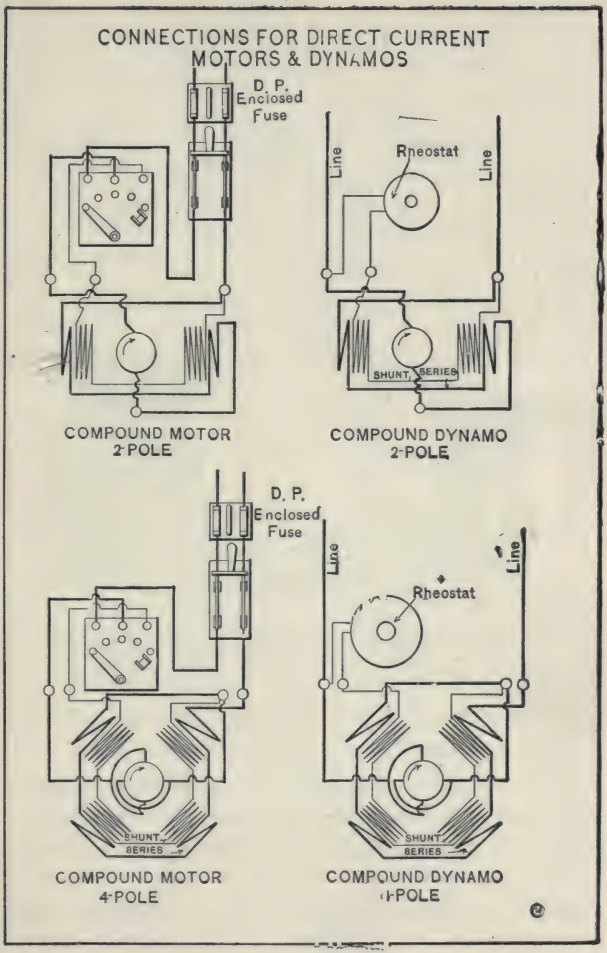
CONNECTIONS FOR DIRECT CURRENT DYNAMOS.



THREE WIRE DISTRIBUTION



MULTIPLE DISTRIBUTION-TWO WIRE


CONNECTIONS FOR DIRECT CURRENT MOTORS & DYNAMOS
D. P. Enclosed Fuse
Line
Rheostat
Line
SHUNT
SERIES
COMPOUND MOTOR 2-POLE
COMPOUND DYNAMO 2-POLE
D. P. Enclosed Fuse
Line
Rheostat
Line
SHUNT
SERIES
SHUNT
SERIES
COMPOUND MOTOR 4-POLE
COMPOUND DYNAMO 4-POLE

OUTSIDE WIRING AND CONSTRUCTION.

Service Wires (those leading from the outside main wire to the buildings and attached to same) should be "Rubber Covered," as described on page 64, under that heading.

Line Wires, other than service wire, should have an approved "weatherproof" covering.

Bare Wires may be used through uninhabited and isolated territories free from all other wires, as in such places wire covering would be of little use, as it is not relied on for pole insulation.

For Insulated Wires.

For Bare Wire or Cable.

Clark Insulator Clamps.

Tie Wires should have an insulation equal to that of the conductors they confine, within city limits, or some permanent clamp that will not injure the insulation.

Space between Wires for outside work, whether for high or low tension, should be at least one foot, and care should be exercised to prevent any possibility of a cross connection by water. Wires should never come in contact with anything except their insulators.

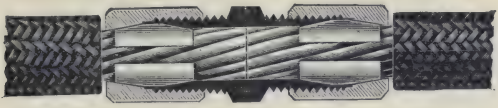
Roof Structures. If it should become necessary to run wires over a building, the wires should be supported on racks which will raise them at least

seven feet above flat roofs, or at least one foot above the ridge of pitched roofs, as shown on page 43, and should be strongly made.

Guard Arms. Whenever sharp corners are turned, each cross arm should be provided with a dead insulated guard arm, or guard iron, to prevent the wires from dropping down and creating trouble, should their insulating support give way.

Petticoat Insulators should be used exclusively for all outside work, and especially on cross arms, racks, roof structures and service blocks. Porcelain knobs, cleats or rubber hooks should never be used for this heavy outside work. In fact, rubber hooks are not now approved for any form of electric light or power work.

Splicing of two pieces of wire or cable should be so done as to be mechanically and electrically



The Dossert Solderless Cable Connector approved for use on stranded wires and cables without the use of solder.

secure without solder. All joints must be soldered, unless made with some form of *approved* splicing device. This ruling applies to joints and splices in all classes of wiring. All joints whether soldered or made with a mechanical splicing device should be covered with an insulation equal to that of the conductors.

Tree Wiring. Whenever a line passes through the branches of trees, it should be properly supported by insulators, as shown on page 41, to pre-

vent the chafing of the wire insulation and grounding the circuit.

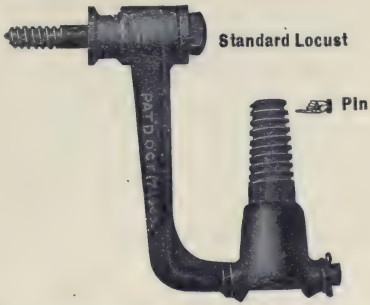
The Dunton tree insulators shown on the opposite page have proved themselves to be the most practical and permanent insulators for all kinds of tree construction, allowing the free swaying of limbs without chafing the insulation of the wires.

Service Blocks which are attached to buildings should have at least two coats of waterproof paint to prevent the absorption of moisture.

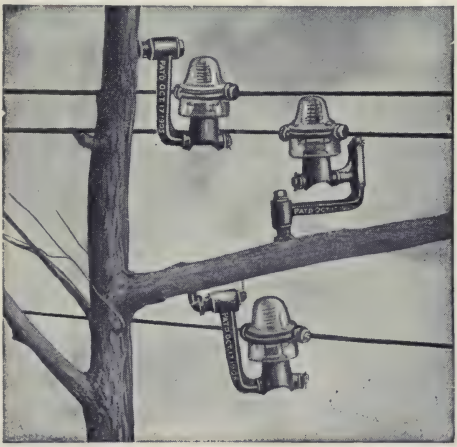
Size of Wire. To find the required size of wire in circular mils for any alternating system, to carry any required current any distance at any voltage and with any required loss for alternating systems, use the formulæ and examples on pages 127 to 140, and for direct currents the formulæ on pages 139 and 140. When possible, however, refer to tables No. 1 or No. 2 on pages 51 and 67, as it will be found much simpler when within their limitations for D. C. work.

Entrance Wires. Where the service wires enter a building they should have drip loops outside and the holes through which the conductors pass should be bushed with non-combustible non-absorptive insulating tubes, such as glass or porcelain, slanting upward toward the inside. See cut on page 59.

For low potential systems the wires of one circuit may be brought into buildings through a single iron conduit. The conduit should be curved downward at its outer end and carefully sealed or equipped with an approved service-head to prevent the entrance of moisture. The outer end should be at



Dunton Tree Insulator for Side of Limb.

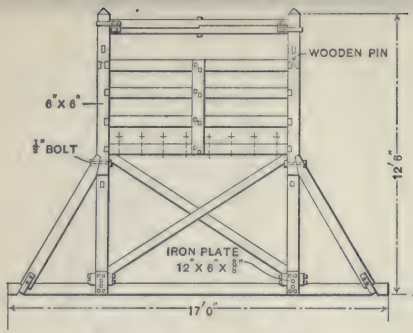


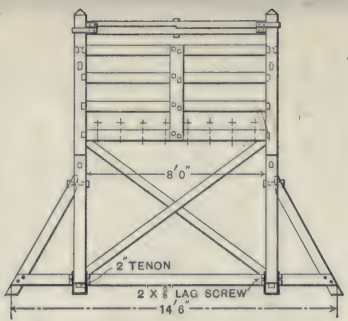
Construction Work—Tree Insulation.

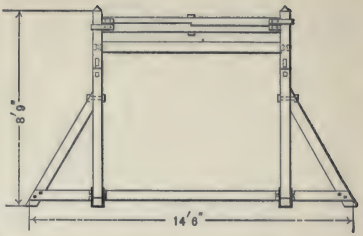
least one foot from any woodwork and the inner end should extend to the service cut-out.

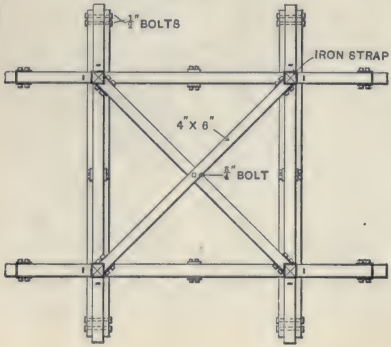
Telegraph and Telephone wires should never be placed on the same cross arm with light or power wires, especially when alternating currents are used, as trouble will arise from induction, unless expensive special construction, such as the transposing of the lighting circuits, be resorted to at regular intervals. Even under these conditions it is bad practice, as an accidental contact between the lighting or power circuit might result in starting a fire in the building to which the telephone line is connected. If, however, it is necessary to place telegraph and telephone wires on the same poles with lighting and power wires, the distance between the two inside pins of each cross arm should not be less than twenty-six inches and the metallic sheaths to cables should be thoroughly and permanently connected to earth.

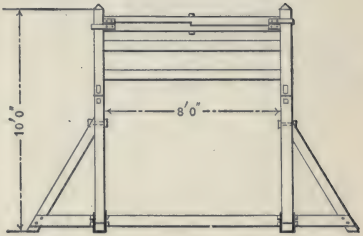
Transformers should not be placed inside of any building excepting central stations or sub-stations and should not be attached to the outside walls of buildings, unless separated therefrom by substantial supports as shown on page 49. In cases where it is impossible to exclude the transformer and primary wiring from entering the building, the transformer should be located as near as possible to the point where the primary wires enter the building, and should be placed in a vault or room constructed of or lined with fire-resisting material, and should contain nothing but the transformers. It is, of course, the safest practice to place all transformers on poles











CONSTRUCTION WORK

Structures for Flat Roofs

away from the building that is to be wired, as illustrated on page 49.

Where transformers are to be connected to high-voltage circuits, it is necessary in many cases, for best protection to life and property, that the secondary system be permanently grounded, and provision should be made for it when the transformers are installed.

Grounding of Low-Potential Circuits. The grounding of low-potential circuits is only recommended when such circuits are so arranged that under normal conditions of service there will be no passage of current over the ground wire.

In Direct-Current 3-Wire Systems, the neutral wire may be grounded, and when grounded the following suggestions should be complied with:

1. They should be grounded at the central station on a metal plate buried in coke beneath permanent moisture level, and also through all available underground water and gas-pipe systems.

2. In underground systems the neutral wire should also be grounded at each distributing box through the box.

3. In overhead systems the neutral wire should be grounded every 500 feet.

In Alternating-Current Secondary Systems. Transformer secondaries of distributing systems should preferably be grounded, and when grounded, the following suggestions should be complied with:—

1. The grounding should be made at the neutral point or wire, whenever a neutral point or wire is accessible.

2. When no neutral point or wire is accessible one side of the secondary circuit may be grounded, provided the maximum difference of potential between the grounded point and any other point in the circuit does not exceed 250 volts.

3. The ground connection should be at the transformer or on the individual service and when transformers feed systems with a neutral wire, the neutral wire should also be grounded at least every 250 feet for overhead systems, and every 500 feet for underground systems.

Inspection Departments having jurisdiction may *require* grounding if they deem it necessary.

Ground Connections. When the ground connection is inside of any building, or the ground wire is inside of, or attached to any building (except central or sub-stations) the ground wire should be of copper and have an approved rubber insulating covering.

The ground wire in direct-current 3-wire systems should not at central stations be smaller than the neutral wire and not smaller than No. 4 B. & S. gage elsewhere. The ground wire in alternating-current systems should never be less than No. 4 B. & S. gage.

On three-phase systems, the ground wire should have a carrying capacity equal to that of any one of the three mains.

The ground wire should, except for central stations and transformer sub-stations, be kept outside of buildings as far as practicable, but may be directly attached to the building or pole by cleats or

straps or on porcelain knobs. Staples should never be used. The wire should be carried in as nearly a straight line as practicable, avoiding kinks, coils and sharp bends, and should be protected when exposed to mechanical injury.

This protection can be secured by use of an approved moulding, and as a rule the ground wire on the outside of a building should be in moulding at all places where it is in within seven feet from the ground.

The ground connections for central stations, transformers, sub-stations, and banks of transformers should be made through metal plates buried in coke below permanent moisture level, and connection should also be made to all available underground piping systems including the lead sheath of underground cables.

For individual transformers and building services, the ground connection may be made to water piping systems running into buildings. This connection may be made by carrying the ground wire into the cellar and connecting on the street side of meters, main cocks, etc.

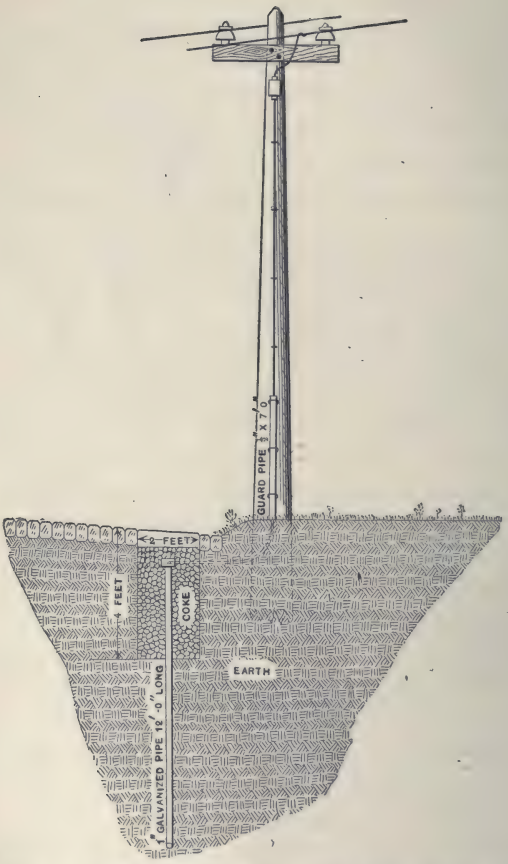
Where it is necessary to run the ground wire through any part of a building it should be protected by approved porcelain bushings through walls or partitions and should be run in approved moulding, except that in basements it may be supported on porcelain.

In connecting a ground wire to a piping system, the wire should be sweat into a lug attached to an approved clamp, and the clamp firmly bolted to the water pipe after all rust and scale have been re-

moved; or be soldered into a brass plug and the plug forcibly screwed into a pipe-fitting, or, where the pipes are cast iron, into a hole tapped into the pipe itself. For large stations, where connnecting to underground pipes with bell and spigot joints, it is well to connect to several lengths, as the pipe joints may be of rather high resistance.

Where ground plates are used, a No. 16 Stubbs' gage copper plate, about three by six feet in size, with about two feet of crushed coke or charcoal, about pea size, both under and over it, would make a ground of sufficient capacity for a moderate-sized station, and would probably answer for the ordinary sub-station or bank of transformers. For a large central station, a plate with considerably more area might be necessary, depending upon the other underground connections available. The ground wire should be riveted to the plate in a number of places, and soldered for its whole length. Perhaps even better than a copper plate is a cast-iron plate with projecting forks, the idea of the fork being to distribute the connection to the ground over a fairly broad area, and to give a large surface contact. The ground wire can probably best be connected to such a cast-iron plate by soldering it into brass plugs screwed into holes tapped in the plate. In all cases, the joint between the plate and the ground wire should be thoroughly protected against corrosion by painting it with waterproof paint or some equivalent.

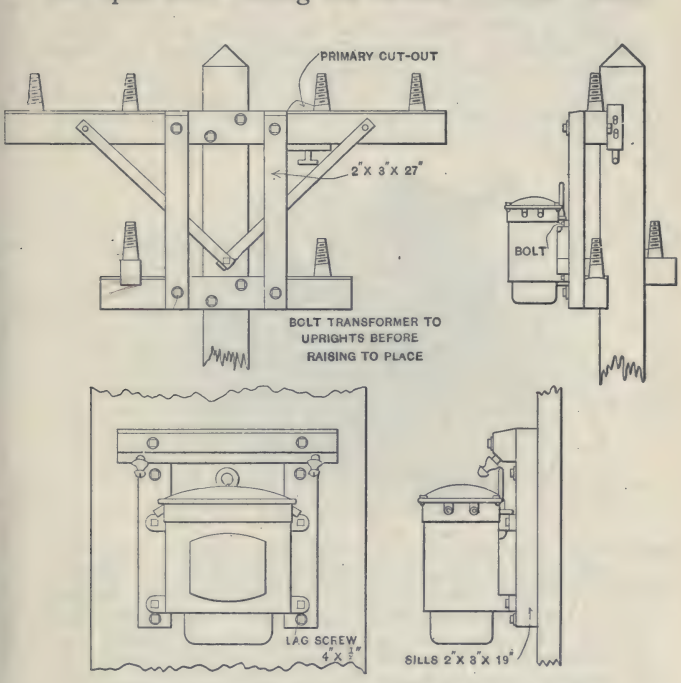
Ground Detectors. The cuts on page 63 illustrate a few practical methods of detecting grounds on alternating and direct-current circuits which have



Installation of Lightning Arrester on outside lines, showing method of obtaining a good "ground."

not been purposely grounded, as described on pages 44 and 45.

In using any one of these methods for detecting grounds always see that the circuit TO GROUND is left open after testing the outside circuits. Some



Construction Work—Installation of Transformers.

central station men are in the habit of leaving the ground circuit closed on one side constantly in order that any ground that might occur on the other side may be instantly noticed. This, however, is bad practice, as it greatly reduces the insulation of the whole system. Test all circuits at least once a day.

It is frequently necessary to know just what the insulation resistance of a line, or the wiring in a building, is in ohms.

Heretofore such tests have been made with some form of portable testing set (Wheatstone Bridge), or by the Voltmeter-method; inconvenient calculations being necessary in either case.

Now, however, there is on the market a new instrument, called the Evershed Megger, by means of which conductor or insulation resistance can be measured as quickly and as accurately as E. M. F. is measured with a Voltmeter. Also a small hand-dynamo is mounted in the case, so that no outside source of current is required.

Tests by the "Megger-method" are made as follows: Connect a wire from one side of the circuit to binding post of the Megger marked "Line," and with another piece of wire connect a water pipe to the "Earth" binding post of the Megger. Turn the dynamo handle at one end of the Megger case, and the pointer of the instrument will instantly show the correct resistance—the scale being graduated in ohms.

As the dynamo voltage is usually 100 or 250 volts, there is the added advantage that tests by the "Megger-method" are practically made under working conditions.

WIRING TABLE NO. 1. FOR DIRECT CURRENT WORK.

Size of Wire, B. & S. Gauge.	Feet per Volt-Ampere.
0000	10068.4
000	7998.7
00	6339.5

0	5025.1
1	3974.5
2	3166.5
3	2495.0
4	1980.0
5	1347.0
6	1248.7
7	986.7
8	779.6
9	618.4
10	495.0
11	394.0
12	312.3
13	246.7
14	194.

How to Use the Wiring Table No. 1. The column entitled size of wire B. & S. Gauge gives the various sizes used in wiring. The column entitled feet per volt-ampere gives the number of feet that the adjacent size of wire will transmit one ampere with a loss of one volt; this is a constant quantity for each size of wire.

The distance that a wire will transmit a given current is directly proportional to the volts lost.

The distance that a wire will transmit a current with a certain volt-loss is inversely proportional to the current.

If, therefore, it is desired to know how far a given wire will transmit a given current at a certain given line loss, select from the second column opposite the size of the wire constant in the feet-per-volt-ampere column and multiply this figure by the desired line loss and divide by the current to be transmitted.

If it is desired to know how much current can be transmitted a given distance with a certain line loss

multiply this constant by the line loss and divide by the distance.

If it is desired to know what line loss will occur when transmitting a certain current through a certain size of wire multiply the distance and current together and divide by the constant for the size of wire which it is desired to use.

Take a Practical Example. Let it be asked, "How far will a No. 6 wire transmit 20 amperes with a line loss of 15 volts?" The constant for No. 6 wire is 1248.7; multiply this by the line loss of 15 volts and we have 18730.5, and dividing this by the current, 20 amperes, we have 936.5. Conversely, suppose we have a distance of 936.5 feet and must transmit over it 20 amperes, how much line loss will obtain? Multiply this distance of 936.5 by the current to be transmitted, and we obtain 18730., dividing this by the constant for No. 6 wire, 1248.7, we obtain 14.999 volts line loss, or practically 15 volts.

Similarly: Suppose we have a distance of 936.5 feet, and the conditions are such that at most it must not exceed a line loss of more than 15 volts. How many amperes can we transmit with a No. 6 wire?

To do this we multiply the constant of No. 6 wire, 1248.7 by the line loss of 15 volts, obtaining 18730.5, and dividing this by the distance, 936.5 feet, we obtain 20.0005, or practically 20 amperes.

Finally, and as is more often the case, the distance and line loss and current are given; we have to multiply the distance by the current and divide by the line loss which will give us the constant of the wire

to use. In the preceding case of 936.5 feet, we multiply by the current of 20 amperes and obtain 18730.; dividing this by the line loss of 15 volts we obtain 12,486.6, which is practically 12,487, the constant for No. 6 wire.

If this constant had been larger still, but not so large as the constant for No. 5 wire, it would be proper to select the nearest constant.

Primary Wiring, Single Phase. Primary wires should be kept at least twelve inches apart, and at that distance from conducting material. Primary wires carrying over 3,500 volts should not be brought into or over any building other than the central power station or sub-station, nor should they run across the front of any building close enough to be in the way of the fire department.

To find the required size of wires for any alternating-current system, refer to the chapter on alternating-current wiring, page 127.

Wires for Outside Use have in most cases a "weather-proof" (see page 65) insulation, except service wires, which should be "rubber covered" (see page 64). Any insulating covering for wires exposed to the weather on poles is in time rendered useless. The real insulation of the system is dependent upon the porcelain or glass insulators.

POLES FOR LIGHT AND POWER WIRES.

It is very essential to a proper installation that the poles receive due consideration, a fact that is too often overlooked.

In selecting the style of pole necessary for a certain class of work, the conditions and circumstances should be considered. They may be arranged in three classes, the size of wire they are to carry being one of the important regulating circumstances.

First Class—Alternating current plants for lighting small towns. Main line of poles should consist of poles of from 30 to 35 feet with 6-inch tops. These are strong enough for all the weight that is placed upon them. No pole less than 30 feet with 6-inch top should be placed on a corner for lamps. The height of trees, of course, will have to be considered in many cases. For the Edison municipal system, where more than one set of wires are used for street lighting, a 6-inch top should be the size of the poles, the length being not less than 30 feet, and more if the streets be hilly and filled with trees.

Second Class—Town lighting by arc lights. All poles should be at least 6-inch tops. The corner poles should be 6½-inch tops, and wherever the cross arms are placed on a pole at different angles, the pole should be at least a 6½-inch top. A 30-foot pole is sufficiently long for the main line, but it would be advisable to place 35-foot poles on corners.

Third Class—Where heavy wire, such as No. 00, is used for feeder wire, the poles should be at least

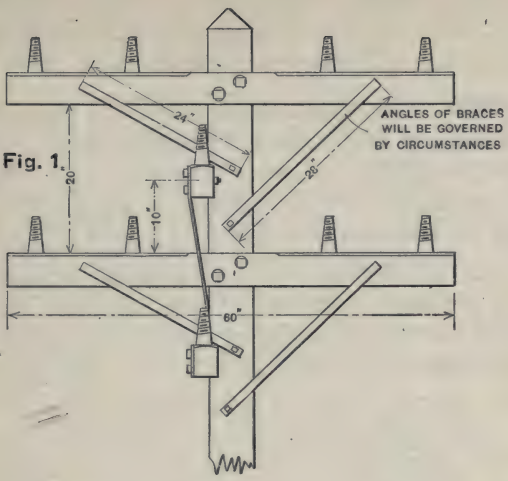


Fig. 1.

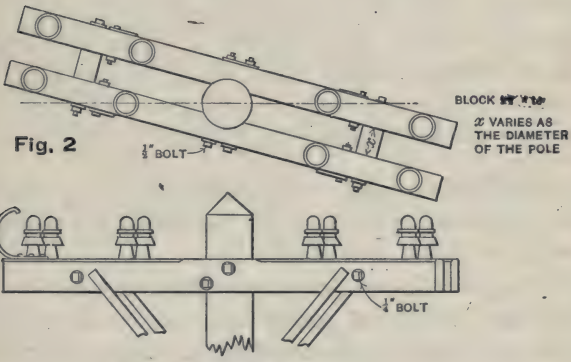


Fig. 2

CONSTRUCTION WORK

Position of Cross-Arms when Turning Corners

When running a heavy line where it is necessary to use two cross arms fastened as shown in Fig. 2. If lines are not heavy, only one cross arm will be necessary. In case lines cross the street diagonally, the arms where the wires leave and those to which they run are both set at an angle. When turning an abrupt corner, only one arm is turned. The above cannot be used where feeders tap into double branches. In such cases the method as given in Fig. 1 is used.

7-inch tops. Where mains are run on the same pole line the strain is somewhat lessened, and poles of smaller size will answer all purposes.

Cull Poles. The question as to what is a cull pole is something on which many authorities differ. Of course, if specifications call for a certain sized pole, parties supplying the poles should be compelled to send the sizes called for. All poles that are smaller at the top than the sizes agreed upon, are troubled with dry rot, large knots and bumps, have more than one bend, or have a sweep of over twelve inches, should certainly be classed as cull poles. Specifications for electric light and power work should be, and in many cases are, much more severe than those required by telegraph lines. A cull pole, one of good material, is the best thing for a guy stub, and is frequently used for this purpose. A cedar pole is always preferable to any other, owing to the fact that it is very light in comparison to other timber, and is strong, durable, and very long lived.

Pole Setting. In erecting poles, it seems to be the universal opinion of the best posted construction men that a pole should be set at least five feet in the ground, and six inches additional for every five feet additional length above thirty-five feet. Also additional depths on corners. Wherever there is much moisture in the ground, it is of much value to paint or smear the butt ends of the pole with pitch or tar, allowing this to extend about two feet above the level of the ground. This protects the pole from rot at the base. The weakest part of the pole is just where it enters the ground. Never set poles

further than 125 feet apart; spacing not over 110 feet is good practice.

Pole Holes should be dug large enough so that the butt of the pole can be dropped straight in without any forcing, and when the pole is in position only one shovel should be used, to fill in, the earth being thoroughly tamped down with iron tampers at every step until the hole is completely filled with solidly packed earth. Where the ground is too soft for proper tamping, a grouting composed of one part of Portland cement to two parts of sand mixed with broken stone may be used to make an artificial foundation.

Painting. When poles are to be painted, a dark olive green color should be chosen, in order that they may be as inconspicuous as possible. One coat of paint should be applied before pole is set, and one after pole is set. Tops should be pointed to shed water.

CEDAR POLES FOR ELECTRIC LIGHT WORK.

SIZE.	Average weight, pounds each.	No. of Poles to a Car	SIZE.	Average weight, pounds each.	No. of Poles to a Ca
25-ft., 5-inch top	200	150	35-ft., 7-inch top	650	90
25 " 5½ " "	225	130	40 " 6 " "	800	80
25 " 6 " "	250	100	40 " 7 " "	900	75
28 " 7 " "	400	80	45 " 6 " "	900	70
30 " 5 " "	300	110	45 " 7 " "	1000	65
30 " 6 " "	350	90	50 " 6 " "	1200	55
30 " 7 " "	420	75	55 " 6 " "	1400	45
35 " 6 " "	550	100			

All poles 35 feet long and over must be loaded on two cars.

For chestnut poles add 50 per cent. to weights as given above.

Cross Arms. The distance from the top of the pole to the cross arm should be equal to the diameter of pole at the top. All cross arms should be well painted with one coat of paint before placing, and must be of standard size as shown in the diagrams. Cross arms of four or more pins should be braced, using one or two braces as occasion demands. Cross arms on one pole should face those on the next, thereby making the cross arms on every other pole face in one direction. All wooden pins should have their shanks dipped in paint and should be driven into the cross arm while the paint is wet. The upper part of the pin should also be painted. Iron pins can be furnished for corners where there is a heavy strain, but are not advised, it being preferable to use the construction as shown in the diagrams. Put double arms on the pole where feeder wires end.

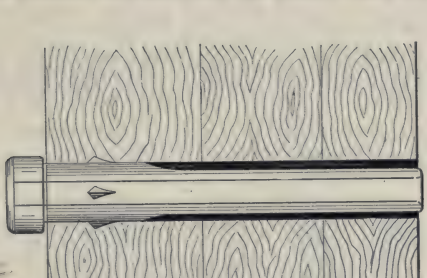
Guard Irons. Guard irons should be placed at all angles in lines and on break arms.

Steps. All junction and lamp poles should be stepped so that the distance between steps on the same side of the pole will not be over 36 inches. Poles carrying converters should also be stepped.

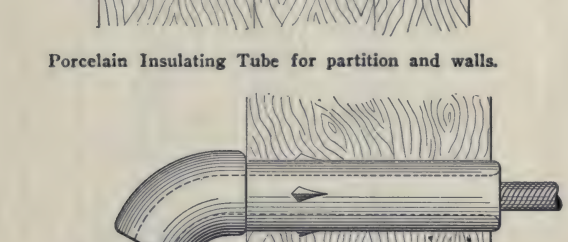
Guys. All poles at angles in the line should be properly guyed, using No. 4 B. & S. galvanized iron wire, or two No. 8 wires twisted. All junction poles should also be guyed. Never attach a guy wire to a pole so that it prevents a cross arm from being removed.

For alternating work, double or triple petticoat insulators are recommended. (See cuts on page 62.) Pole brackets, except in connection with the tree insulators, should not be used.

Tape should be secured at either end of a joint



Porcelain Insulating Tube for partition and walls.



Porcelain Tube, to be used where wires enter buildings from outside, showing drip loop in wire.

by a few turns of twine. When looping for lamps, etc., leave coiled sufficient wire, without waste, to reach lamp or building without joints. In cutting arc or incandescent lamps into an existing circuit, use a piece of "rubber covered" wire (see page 64).

POLE LINE DATA

Gauge No. B. & S.	4-0	3-0	2-0	1-0	1	2
Diam. Bare wire, in Thousandths	.460	.40964	.3648	.3249	.2893	.2576
Ohms Res. B. wire at 75° per mile	.2622	.33	.4164	.5252	.6642	.8337
Wt. (lbs.) per 1,000 ft. Triple B. .	775	630	490	400	306	268
Wt. " " Mile " " . .	4092	3326	2587	2112	1616	1415

Poles per Mile	Dist. bet. Poles—Ft.						
20	264.00	210.73	171.31	133.24	108.78	83.21	72.87
21	251.40	200.66	163.14	126.87	103.58	77.24	69.39
22	240.10	191.64	155.81	121.17	98.91	75.67	66.27
23	229.56	183.24	148.96	115.85	94.57	72.36	63.36
24	220.00	175.60	142.76	111.03	90.64	69.34	60.72
25	211.20	168.59	137.04	106.58	87.01	66.56	58.29
26	203.07	162.07	131.76	102.48	83.65	64.00	56.05
27	195.55	156.10	126.90	98.69	80.56	61.64	53.97
28	188.55	150.46	122.35	95.16	77.68	59.43	52.05
29	182.09	145.34	118.16	91.89	75.01	57.39	50.26
30	176.00	140.50	114.21	88.83	72.51	55.47	48.58
31	170.30	135.92	110.51	85.95	70.16	53.67	47.00
32	165.00	131.71	107.07	83.28	67.98	52.01	45.55
33	160.00	127.72	103.82	80.75	65.92	50.43	44.16
34	155.29	123.96	100.76	78.37	63.98	48.94	42.86
35	150.85	120.38	97.89	76.14	62.15	47.55	41.64
36	146.66	117.07	95.15	74.02	60.43	46.23	40.48
37	142.70	113.90	92.60	72.02	58.79	44.98	39.39
38	138.96	110.93	90.17	70.13	57.25	43.88	38.36
39	135.38	108.05	87.84	68.33	55.77	42.67	37.37
40	132.00	105.37	85.65	66.62	54.38	41 61	36.43
41	128.78	102.79	83 56	64.99	53.05	40.59	35.54
42	125.71	100.35	81.58	63.44	51.79	39.62	34.70
43	122.79	98.01	79.68	61.97	50.59	38.70	33.89
44	120.00	95.79	77.87	60.56	49.47	37.82	33.12
45	117.33	93.66	76.15	59.21	48.38	36.98	32.38
46	114.78	91.61	74.48	57.93	47.27	36.18	31.68
47	112.34	89.67	72.89	56.70	46 28	35.40	31 01
48	110.00	87.80	71.38	55.52	45.32	34.67	30.36
49	107.75	86.01	69.92	54.38	44.39	33.96	29.74
50	105.60	84.30	68.53	53.29	43.50	33.28	29.15
51	103.52	82.63	67.18	52.24	42.65	32.63	28.57
52	101.53	81.04	65.89	51.24	41.83	32.00	28.02
53	99.64	79.54	64.65	50.29	41.05	31.40	27.50
54	97.77	78.04	63.44	49.34	40.28	30.82	26.98
55	96.00	76.63	65.29	48.45	39.55	30.25	26.50

POLE LINE DATA—*Continued.*

Gauge No. B. & S.	No. 3	No. 4	No. 5	No. 6.	No. 7	No. 8
Diam. Bare Wire, Thousandths	.2294	.2043	.1819	.1620	.1442	.1285
Res. B. Wire, per mile at 75°	1.058	1.333	1.6748	2.114	2.673	3.387
Wt. 1.000 ft. Triple Braid	210	164	145	112		78
Wt. Mile " "	1109	866	766	591		412

Poles Per Mile	Distance Between Poles —Feet	Approximate Wt. of Triple Braid Wire between Poles					
20	264.00	57.10	44.59	39.43	30.45	.....	21.21
21	251.40	54.38	42.46	37.54	29.00	.....	20.20
22	240.10	51.93	40.55	35.86	27.70	.....	18.29
23	229.56	49.65	38.77	34.28	26.48	.....	18.44
24	220.00	47.59	37.16	32.86	25.38	.....	17.67
25	211.20	45.68	35.68	31.54	24.36	.....	16.97
26	203.07	43.92	34.30	30.33	23.42	.....	16.32
27	195.55	42.29	33.03	29.21	22.56	.....	15.71
28	188.55	40.78	31.85	28.16	21.75	.....	15.15
29	182.09	39.39	30.76	27.19	21.00	.....	14.63
30	176.00	38.07	29.73	26.29	20.30	.....	14.14
31	170.30	36.83	28.77	25.43	19.64	.....	13.68
32	165.00	35.69	27.87	24.64	19.03	.....	13.26
33	160.00	34.61	27.03	23.90	18.46	.....	12.85
34	155.29	33.59	26.23	23.19	17.91	.....	12.47
35	150.85	32.63	25.48	22.53	17.40	.....	12.12
36	146.66	31.72	24.78	21.90	16.92	.....	11.78
37	142.70	30.87	24.10	21.31	16.46	.....	11.46
38	138.96	30.06	23.47	20.76	16.03	.....	11.16
39	135.38	29.28	22.86	20.22	15.62	.....	10.88
40	132.00	28.55	22.30	19.71	15.23	.....	10.61
41	128.78	27.85	21.75	19.23	14.85	.....	10.34
42	125.71	27.19	21.24	18.78	14.50	.....	10.10
43	122.79	26.56	20.74	18.34	14.17	.....	9.86
44	120.00	25.96	20.27	17.92	13.84	.....	9.64
45	117.33	25.38	19.82	17.52	13.53	.....	9.43
46	114.78	24.83	19.39	17.14	13.24	.....	9.22
47	112.34	24.30	18.98	16.78	12.96	.....	9.02
48	110.00	23.79	18.58	16.43	12.69	.....	8.84
49	107.75	23.31	18.20	16.09	12.43	.....	8.66
50	105.60	22.84	17.84	15.77	12.18	.....	8.48
51	103.52	22.39	17.49	15.46	11.95	.....	8.32
52	101.53	21.96	17.15	15.16	11.71	.....	8.16
53	99.64	21.55	16.83	14.88	11.49	.....	8.00
54	97.77	21.15	16.51	14.60	11.28	.....	7.85
55	96 00	20.76	16.21	14 34	11.07	.....	7.71

Primary Wires on Poles. When using alternating current and running more than one circuit of primaries upon the same line of poles the wires of each circuit should be run parallel and on adjacent pins, as shown below, so as to avoid any fluctuation in the lamps due to induction. The lines letteed A and A are for circuit No. 1 and B and B for circuit No. 2, etc.

A

A

B

B

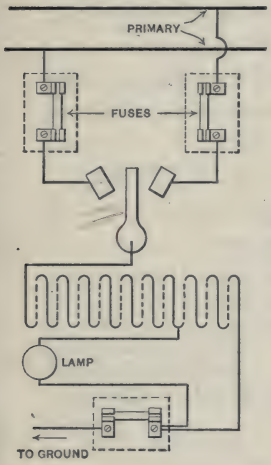
When connecting transformers to 1000-volt mains a double-pole cut-out is placed in the primary circuit. For 2000-volt circuits a single-pole cut-out should be placed in each side of the line, thus avoiding any possible short circuit due to an arc being established across the contacts of the double-pole cut-out. This, owing to the great difference of potential between opposite poles, is liable to occur when the fuses "blow."

6000 Volts 4000 Volts 15000 Volts

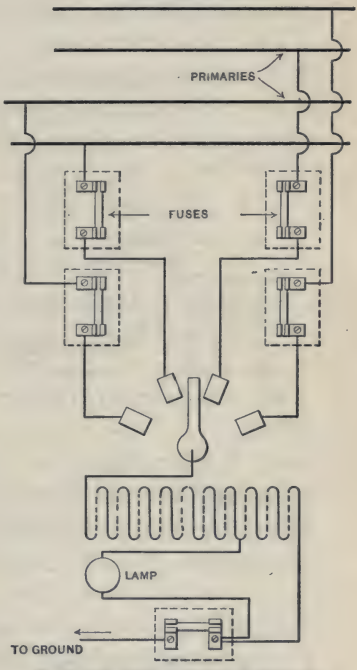
Types of Petticoat Insulators for high voltages.

CONNECTIONS
OF
GROUND DETECTORS

ALTERNATING
GROUND DETECTOR
FOR ONE CIRCUIT

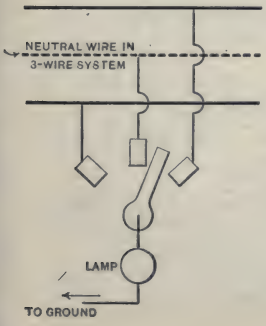


ALTERNATING
GROUND DETECTOR
FOR TWO CIRCUITS



IF THE LAMP BURNS A GROUND IS INDICATED ON THE OPPOSITE SIDE OF THE CIRCUIT FROM THAT TO WHICH THE SWITCH IS CONNECTED

DIRECT CURRENT
GROUND DETECTOR



INSIDE WIRING.

Approved "Rubber Covered" Wire should be used exclusively in all interior wiring. Although the Fire Underwriters allow "Slow Burning" wire to be used in dry places when wiring is entirely exposed to view and rigidly supported on porcelain or glass insulators "Rubber Covered" wire is preferable.

The copper conductors before being rubber covered should be thoroughly tinned and the thickness of the rubber covering should correspond to the following table for voltages up to 600.

From No.	18	to No.	16	inclusive	$\frac{1}{32}$ in.
"	15	to "	8	"	$\frac{3}{64}$ in.
"	7	to "	2	"	$\frac{1}{16}$ in.
"	1	to "	0000	"	$\frac{5}{64}$ in.
"	0000	to "	500000 c. m.	"	$\frac{3}{32}$ in.
"	500000 c. m.	to "	1000000 "	"	$\frac{7}{64}$ in.
Larger than		"	1000000 "	"	$\frac{1}{8}$ in.

For voltages between 601 and 3500.

From No. 14 to No.	1	inclusive	$\frac{3}{32}$ in.	
" 0 to "	500000 c. m.	"	$\frac{3}{32}$ in.	covered by braid or tape.
Larger than "	500000 "	"	$\frac{4}{32}$ in.	

Manufacturers of Approved "Rubber Covered" Wires:

Acme Rubber Mfg. Co., Trenton, N. J.
American Electrical Works, Providence, R. I.
American Steel and Wire Co., Worcester, Mass.
Atlantic Ins. Wire and Cable Co., New York.
Bay State Wire and Cable Co., Hyde Park, Mass.
Belden Mfg. Co., Chicago, Ill.
Bishop Gutta Percha Co., New York, N. Y.
Boston Insulated Wire and Cable Co., Boston, Mass.
Bourn Rubber Co., Providence, R. I.
Collyer Insulated Wire & Cable Co., Pawtucket,
Consumers' Rubber Co., Bristol, R. I.
Crescent Insulated Wire and Cable Co., Trenton.
Detroit Insulated Wire Co., Detroit, Mich.

Diamond Rubber Co., Akron, O.
Electric Cable Co., Bridgeport, Conn.
General Electric Co., Schenectady, N. Y.
Goodyear Rubber Insulating Co., New York, N. Y.
Habirshaw Wire Co., Yonkers, N. Y.
Hazard Mfg. Co., Wilkesbarre, Pa.
Home Rubber Co., Trenton, N. J.
Indiana Rubber and Ins. Wire Co., Jonesboro, Ind.
Kerite Insulated Wire & Cable Co., New York.
Lowell Insulated Wire Co., Lowell, Mass.
Marion Insulated Wire & Rubber Co., Marion, Ind.
National India Rubber Co., Bristol, R. I.
New York Insulated Wire Co., New York, N. Y.
Okonite Co., Limited, New York, N. Y.
Phillips Insulated Wire Co., Pawtucket, R. I.
Roebling's, John A., Sons Co., Trenton, N. J.
Rome Wire Co., Rome, N. Y.
Safety Insulated Wire and Cable Co., New York.
Simplex Electrical Co., Boston, Mass.
Standard Underground Cable Co., Pittsburg, Pa.
Waterbury Co., New York, N. Y.

"Slow Burning" Wire should have an insulation consisting of three braids of cotton or other thread with the interstices well filled with a fireproofing compound. The outer braid should be designed to resist abrasion and have its surface finished smooth and hard.

The complete covering should be of a thickness not less than that given in the following table:

From	No.	14	to	No.	8	inclusive
"	"	7	to	"	2	"
"	"	1	to	"	0000	"
"	"	0000	to	"	500000 c. m.	"
"	"	500000	to	"	1000000 c. m.	"
Larger than				"	1000000 c. m.	"

"Weatherproof" Wire is for out-door use, and should have a covering of at least three braids thoroughly impregnated with a dense moisture repellent

which should stand a temperature of 160° Fahrenheit without dripping. The thickness should correspond to that of "Slow Burning Weatherproof" and the outer surface should be thoroughly slicked down.

Carrying Capacity of Wires. The table on page 74 gives the safe carrying capacity of wires from No. 18 B. & S. to cables of 2,000,000 circular mils. No wires smaller than No. 14 should be used except for fixture wiring and pendants in which cases as small as No. 18 may be used. (See pages 88 and 89.)

Tie Wires should have an insulation equal to that of the conductors they confine.

Splicing should be done so as to make the wires mechanically and electrically secure without solder; then they should be soldered to insure preservation from corrosion and consequent heating from poor contact.

All joints should be soldered unless made with some form of *approved* splicing device such as Dossert joints. (See page 39.) This ruling applies to joints and splices in all classes of wiring.

Stranded Wires should have their tips soldered before being fastened under clamps or binding screws. When the stranded wires have a conductivity greater than No. 8 B. & S. copper wire they should be soldered into lugs, unless Dossert lugs are used.

Wiring Table, No. 2. The following examples show the method of using the table on opposite page.

1. What size of wire should we use to run 50 50-watt carbon lamps, of 110 volts, a distance of 150 feet to the center of distribution with the loss

WIRING TABLE FOR LIGHT AND POWER CIRCUITS.

Multiply current in amperes by single distance and refer to the nearest corresponding number under column of Actual Volts Lost, to find size of wire.

Volts.	Percentage of Loss.																
2000	1.7	1.5	1.4	1.2	1.1	1.0	0.75	0.5	0.45	0.4	0.35	0.3	0.25	0.2	0.15	0.1	0.05
1000	3.4	2.9	2.7	2.4	2.2	2.0	1.5	1.0	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0 1
500	6.5	5.7	5.2	4.8	4.3	3.9	2.9	2.0	1.8	1.6	1.4	1.2	1.0	0.8	0.6	0.4	0.2
220	13.7	12.0	11.0	10.3	9.3	8.3	6.5	4.4	3.9	3.5	3.1	2.7	2.2	1.8	1.4	0.9	0.45
110	—	—	20.0	18.5	17.0	15.4	12.0	8.4	7.6	6.8	6.0	5.2	4.4	3.5	2.7	1.8	0.9
52	—	—	—	—	—	—	22.4	16.1	14.7	13.3	11.8	10.3	8.8	7.1	5.5	3.7	1.9

Carrying Capacity *Amperes	Size B. & S.	Actual Volts Lost. 35	30	27.5	25	22.5	20	15	10	9	8	7	6	5	4	3	2	1
	0000	345800	296400	271700	247000	222300	197600	148200	98800	88920	79040	69160	59280	49400	39520	29640	19760	9880
177	000	274400	235200	215600	196000	176400	156800	117600	78400	70560	62720	54880	47040	39200	31360	23520	15680	7840
150	00	217525	186450	170912	155375	139837	124300	93225	62150	55935	49720	43505	37290	31075	24860	18645	12430	6215
127	0	172550	147900	135575	123250	110925	98600	73950	49300	44370	39440	34510	29580	24650	19720	14790	9860	4930
107	1	136850	117300	107525	97750	87975	78200	58650	39100	35190	31280	27370	23460	19550	15640	11730	7820	3910
90	2	108500	93000	85250	77500	69750	62000	46500	31000	27900	24800	21700	18600	15500	12400	9300	6200	3100
76	3	86100	73800	67650	61500	55350	49200	36900	24600	22140	19680	17220	14760	12300	9840	7380	4920	2460
65	4	68250	58500	53625	48750	43875	39000	29250	19500	17550	15600	13650	11700	9750	7800	5850	3900	1950
54	5	54250	46500	42625	38750	34875	31000	23250	15500	13950	12400	10850	9300	7750	6200	4650	3100	1550
46	6	43050	36900	33825	30750	27675	24600	18450	12300	11070	9840	8610	7380	6150	4920	3690	2460	1230
33	8	26985	23130	21202	19275	17347	15420	11565	7710	6939	6168	5397	4626	3855	3084	2313	1542	771
24	10	16975	14550	13337	12125	10912	9700	7275	4850	4365	3880	3395	2910	2425	1940	1455	970	485
17	12	10675	9150	8388	7625	6862	6100	4575	3050	2745	2440	2135	1830	1525	1220	915	610	305
12	14	6720	5760	5280	4800	4320	3840	2880	1920	1728	1536	1344	1152	960	768	576	384	192
6	16	4235	3630	3328	3025	2723	2420	1815	1210	1089	968	847	726	605	484	363	242	121

NOTE.—In case a larger loss than any given in the table is required, proceed as follows:—Divide the ampere feet by 10 and then refer to column of Actual Volts Lost divided by 10, from which we find the size wire as before. For examples worked out to illustrate the use of the above table see pages 66 to 69.

* Rubber insulation. For carrying capacity of weatherproof insulated wires. See table on p. 74, 4th column.

of 2 volts? First multiply the amperes, which will be 22.75 (50-50 watt 110-v. lamps take 22.75 amperes, see table on page 102), by the distance, 150 feet, which will equal 3412 ampere-feet. Then refer to the columns headed "Actual Volts Lost," and as we are to have only a loss of two volts look down the column headed 2 until you come to the nearest corresponding number to 3412 and we find that 3900 is the best number to use. Put your pencil on the number 3900 and follow that horizontal column to the left until you come to the vertical column headed "Size B. & S." and you find that a No. 4 B. & S. wire will be the proper size to use in this case.

2. What size wire should we use to carry current for a motor that requires 30 amperes and 220 volts, and is situated 200 feet from the distributing pole, the "drop" in volts not to exceed 2 per cent? First multiply 30 amperes by 200 feet, as we did in the first example, and we get 6000 ampere feet. Now look at the upper left hand corner of the table and you will see a vertical column headed "Volts." Go down this column until you come to 220 and follow the horizontal column to the right until you come to the figure 1.8, which is the nearest we can come to a 2 per cent. loss without a greater loss or "drop." Place your pencil on a figure 1.8 and follow down the vertical column of figures until you come to the nearest corresponding figure to 6000, which we find to be 6200. Then with your pencil on this figure follow the horizontal column to the left and we find that a No. 5 B. & S. wire is a proper size to use for the above conditions.

3. Supposing we have occasion to inspect a piece

of wiring, and find a dynamo operating 50-50 watt 110-volt lamps at a distance of 150 feet, and our wire gauge shows that wire in use is a No. 12 B. & S., at what loss, or "drop," are these lamps being operated? First multiply the amperes, which will be 22.75 (50-50 watt 110-v. lamps take 22.75 amperes, see table on page 102), by the distance, 150 feet and we get 3412 ampere feet. As we find in use a No. 12 B. & S. wire we look for the vertical column headed "Size B. & S." and follow it down until we come to 12. With our pencil on the figure 12 we travel along the horizontal line to the right until we come to the nearest corresponding number to 3412, which we find to be 3050. Then starting at this number we travel up the vertical column and we find a loss of about 10 actual volts, or at an 8 per cent. loss, which would greatly reduce the candle-power or brilliancy of his lamps. A larger wire should, therefore be used.

Installation of Wires. All wiring should be kept free from contact with gas, water or other metallic piping, or any other conductors or conducting material which they may cross, by some continuous and firmly fixed non-conductor, creating a separation of at least one inch, and in wet places should be arranged so that an air space will be left between conductors and pipes in crossing, and the former must be run in such a way that they cannot come in contact with the pipe accidentally. Where one wire crosses another wire the best and usual means of separating them is by a porcelain tube on one of the wires. (Fig. 13, page 107.) The tubing should be prevented from moving out of place either by a cleat

or knob on each end, or by taping it securely in place.

The same method may be adopted where wires pass close to iron pipes, beams, etc., or, where the wires are above the pipes, as is generally the case, ample protection can frequently be secured by supporting the wires with a porcelain cleat placed as nearly above the pipe as possible.

TABLE OF DIMENSIONS AND RESISTANCES OF COPPER WIRE.

B. & S. Gauge No.	Diam. Mils.	Area. Circ. Mils. B. and S. Gauge.	BARE WIRE.			INSULATED WIRE.		
			Lbs. per 1000 ft.	Lbs. per Mile.	Ft. per Pound.	Lbs. per 1000 ft.	Lbs. per Mile.	Ft. per Pound.
0000	460.	211,600	640.73	3383.04	1.56	716	3781.	1.39
000	410.	168,100	508.12	2687.85	1.97	575	3036.	1.74
00	365.	133,225	402.97	2127.66	2.48	465	2455.	2.15
0	325.	105,625	319.74	1688.20	3.13	375	1980.	2.67
1	289.	83,521	253.43	1338.10	3.95	285	1505.	3.51
2	258.	66,564	200.98	1061.17	4.98	245	1294.	4.08
3	229.	52,441	159.38	841.50	6.28	190	1003.	5.26
4	204.	41,616	126.40	667.38	7.91	152	803.	6.58
5	182.	33,124	100.23	529.23	9.98	120	634.	8.34
6	162.	26,244	79.49	419.69	12.58	98	518.	10.20
7	144.	20,736	63.03	332.82	15.86			
8	128.	16,384	49.99	263.96	20.00	66	349.	15.15
9	114.	12,996	39.65	209.35	25.22			
10	102.	10,404	31.44	165.98	31.81	45	238.	22.22
11	91.	8,281	24.93	131.65	40.11			
12	81.	6,561	19.77	104.40	50.58	30	158.	33.33
13	72.	5,184	15.68	82.792	63.78			
14	64.	4,096	12.44	65.658	80.42	20	106.	50.00
15	57.	3,249	9.86	52.069	101.40			
16	51.	2,601	7.82	41.292	127 87	14	74.	71.40
17	45.	2,025	6.20	32.746	161.24			
18	40.	1,600	4.92	25.970	203.31	10	53.	100.00
19	36.	1,296	3.90	20.594	256.39			
20	32.	1,024	3.09	16.331	323.32			

Wires should be run over rather than under pipes upon which moisture is likely to gather, or which by leaking might cause trouble on a circuit. No smaller size than No. 14 B. & S. gauge should ever

TENSILE STRENGTH OF COPPER WIRE.

Numbers, B. & S. G.	Breaking weight, Pounds.		Numbers, B. & S. G.	Breaking weight. Pounds.	
	Hard-drawn.	Annealed.		Hard-drawn.	Annealed
0 000	8 310	5 650	9	616	349
000	6 580	4 480	10	489	277
00	5 226	3 553	11	388	219
0	4 558	2 818	12	307	174
1	3 746	2 234	13	244	138
2	3 127	1 772	14	193	109
3	2 480	1 405	15	153	87
4	1 967	1 114	16	133	69
5	1 559	883	17	97	55
6	1 237	700	18	77	43
7	980	555	19	61	34
8	778	440	20	48	27

The strength of soft copper wire varies from 32,000 to 36,000 pounds per square inch, and of hard copper wire from 45,000 to 68,000 pounds per square inch, according to the degree of hardness.

EQUIVALENT CROSS SECTIONS OF WIRES.

BROWN & SHARP GAUGE.

0000	2— 0	4— 3	8— 6	16— 9	32—12	64—15	128—18
000	2— 1	4— 4	8— 7	16—10	32—13	64—16	.....
00	2— 2	4— 5	8— 8	16—11	32—14	64—17	1 and 3
0	2— 3	4— 6	8— 9	16—12	32—15	64—18	2 " 4
1	2— 4	4— 7	8—10	16—13	32—16	.....	3 " 5
2	2— 5	4— 8	8—11	16—14	32—17	.....	4 " 6
3	2— 6	4— 9	8—12	16—15	32—18	.....	5 " 7
4	2— 7	4—10	8—13	16—16	.....	.....	6 " 8
5	2— 8	4—11	8—14	16—17	.....	.....	7 " 9
6	2— 9	4—12	8—15	16—18	.....	.....	8 " 10
7	2—10	4—13	8—16	.....	.....	.....	9 " 11
8	2—11	4—14	8—17	.....	.....	.....	10 " 12
9	2—12	4—15	8—18	.....	.....	.....	11 " 13
10	2—13	4—16	.....	.....	.....	.....	12 " 14
11	2—14	4—17	.....	.....	.....	.....	13 " 15
12	2—15	4—18	.....	.....	.....	.....	14 " 16
13	2—16	.....	.....	.....	.....	.....	15 " 17
14	2—17	.....	.....	.....	.....	.....	16 " 18
15	2—18	.....	.....	.....	.....	.....	.....

be used for any lighting or power work, not that it may not be electrically large enough but on account of its mechanical weakness and liability to be stretched or broken in the ordinary course of usage. Smaller wire may be used for fixture work, if provided with approved rubber insulation.

Wires should never be laid in or come in contact with plaster, cement or any finish, and should never be fastened by staples, even temporarily, but always supported on porcelain or glass insulators or cleats which will separate the wires at least one-half inch from the surface wired over and keep the wires not less than two and one-half inches apart; three wire cleats may be used when the neutral wire is run in the center and at least two and one-half inches separate the two outside or + and — wires. This style of wiring is intended for low voltage systems (300 volts or less), and when it is all open work, rubber covered wire is not necessary as "weatherproof" wire may be used. Weatherproof wire should not be used in moulding. Wires should not be fished between floors, walls or partitions or in concealed places for any great distance, and only in places when the inspector can satisfy himself that the rules have been complied with, as this style of work is always more or less uncertain.

Twin wires should never be used, except in conduits or when flexible conductors are necessary; they are always unsafe for light or power circuits on account of the short distance between them.

All wiring should be protected on side walls from mechanical injury. This may be done by putting a substantial boxing about the wires, allowing an air

space of one inch around the conductors and closed at the top (the wire passing through bushed holes) and the boxing extending about five feet above the floor. Sections of iron armored conduit may be used (the wire being protected by approved flexible tubing), and in most cases this practice is preferable. All bushings should be made of non-combustible, non-absorptive insulating material such as glass or porcelain and should be used wherever wires go through walls, floors, timbers or partitions. They should be long enough to bush the entire length of the hole in one continuous piece, or else the hole must first be bushed by a continuous waterproof tube. This tube may be a conductor, such as iron pipe, but in that case the wire must be protected by *approved* flexible tubing extending far enough to keep the wire absolutely out of contact with the pipe.

If, however, iron pipes are used with alternating currents, the two or more wires of a circuit should always be placed in the same conduit. If plain iron pipe be used the insulation of that portion of each wire within the pipe should be reinforced by a tough *approved* flexible tubing projecting beyond the iron tubing.

When crossing floor timbers in cellars or in rooms when they might be exposed to injury, wires should be attached, by their insulating supports, to the under side of wooden strips not less than one-half inch in thickness and not less than three inches wide.

When wires are run immediately under roofs, or in proximity to water tanks or pipes they will be considered as exposed to moisture and care should be taken as described on page 77, "Special Wiring."

CARRYING CAPACITIES AND DIMENSIONS OF WIRES AND CABLES.

As adopted by the Fire Underwriters of the United States.
For further dimensions of bare and insulated wires, see Index.

Gauge No. B. & S.	Diameter Mils.	Area Circular Mils.	No. Amperes Weatherproof Insulation.	No. Amperes Rubber Covered	Ohms Per 1000 Ft.	Lbs. Per 1000 Ft. Bare.	1000 Lbs. per ft. Insulated	No. and Size of Wires for Cables.
18.....	40	1,600	5	3	6.3880	4.92	16	
17.....	45	2,025	6	4	5.0660	6.20		
16.....	51	2,601	8	6	4.0176	7.82	20	
15.....	57	3,249	10	8	3.1860	9.86		
14.....	64	4,096	16	12	2.5266	12.44	26	
13.....	72	5,184	19	14	2.0037	15.68		
12.....	81	6,561	23	17	1.5890	19.77	35	
11.....	91	8,281	27	21	1.2602	24.93		
10.....	102	10,404	32	24	.99948	31.44	55	
9.....	114	2,996	39	29	.79242	39.65		
8.....	128	16,384	46	33	.62849	49.99	78	
7.....	144	20,736	56	39	.49845	63.03		
6.....	162	26 244	65	45	.39528	79.49	112	
5.....	182	33,124	77	54	.31346	100.23	145	
4.....	204	41,616	92	65	.24858	126.40	164	
3.....	229	52,441	110	76	.19714	159.38	210	
2.....	258	66 564	131	90	.15633	200.98	268	
1.....	289	83,521	156	107	.12398	253.43	306	
0.....	325	105,625	185	127	.09827	319.74	400	
00.....	365	133,225	220	150	.07797	402.97	490	
000.....	410	168,100	262	177	.06134	508.12	630	
0000.....	460	211 600	312	210	.04904	640.73	775	
Cables...	630	300,000	400	270	.03355	932		37-090
"	727.3	400,000	500	330	.02516	1242		37-1039
"	814.5	500,000	590	390	.02013	1553		61-0905
"	891.9	600,000	680	450	.01666	1863		61-0991
"	963.9	700,000	760	500	.01438	2174		61-1071
"	1030.5	800,000	840	550	.01258	2474		61-1145
"	1092.6	900,000	920	600	.01118	2795		61-1214
"	1152	1,000,000	1000	650	.01006	3106		61-128
"	1208.7	1,100,000	1080	690	.00915	3416		61-.343
"	1262.8	1,200,000	1150	730	.00838	3727		91-1148
"	1314.5	1,300,000	1220	770	.00769	4038		91-1195
"	1364	1,400,000	1290	810	.00715	4348		91-124
"	1413.5	1,500,000	1360	850	.00667	4658		91-1285
"	1458.6	1,600,000	1430	890	.00625	4968		91-1326
"	1503.7	1,700,000	1490	930	.00588	5278		91-1367
"	1547.7	1,800,000	1550	970	.00556	5588		127-1195
"	1571.9	1,900,000	1610	1010	.00527	5898		127-1223
"	1630.2	2,000,000	1670	1050	.00500	6208		127-1254

See Table on Page 57 for various Sizes, from No. 15 to 0000.

Weight of insulation on cables varies for different kinds of work.

The lower current carrying limit (fifth column) is specified for rubber-covered wires to prevent gradual deterioration of the high insulations by the heat of the wires, but not from fear of igniting the insulation.

The carrying capacity of Nos. 16 and 18, B. & S. gauge wire is given, but no smaller than No. 14 should be used for general wiring purposes.

Series Arc Wiring. All wiring in buildings for constant current series arc lighting should be with approved rubber covered wire and the circuit arranged to enter and leave the building through an approved double contact service switch, which means a switch mounted on a non-combustible non-absorptive insulating base and capable of closing the main circuit and disconnecting the branch wires when turned "off"; this switch must be so constructed that it will be automatic in action, not stopping between points when started, and must prevent an arc between points under all circumstances, and must indicate, upon inspection, whether the current be "on" or "off." Such a switch is necessary to cut the high voltage current completely out of the building by firemen in case of fire or when it becomes necessary to make any changes in the lamps or wiring. It should be in a non-combustible case.

This class of wiring should never be concealed or incased except when requested by the Electrical Inspector, and should always be rigidly supported on porcelain or glass insulators which will separate the wiring at least one inch from the surface wired over, and should be kept at least eight inches from each other. No wires carrying a potential of over 3500 volts should be carried into or over any building except central stations and sub-stations. All arc light wiring should, on side walls, be protected from mechanical injury by a substantial boxing, retaining an air space of one inch around the conductors, closed at the top (the wires passing through bushed holes), and extending not less than seven feet from the floor. When crossing floor timbers

in cellars, or in rooms where they might be exposed to injury, wires should be attached by their insulating supports to the under side of a wooden strip not less than one-half an inch in thickness. Instead of the running-boards, guard strips on each side of and close to the wires will be sufficient. These strips to be not less than seven-eighths of an inch in thickness and at least as high as the insulators.

Except on joisted ceilings, a strip one-half of an inch thick is not considered sufficiently stiff and strong. For spans of say eight or ten feet, where there is but little vibration, one-inch stock is generally sufficiently stiff; but where the span is longer than this or there is considerable vibration, still heavier stock should be used.

Arc Lamps should be carefully isolated from inflammable material, and should be provided at all times with a glass globe surrounding the arc, and securely fastened upon a closed base. Broken or cracked globes should not be used.

They should be provided with a wire netting (having a mesh not exceeding one and one-fourth inches) around the globe, and an *approved* spark arrester when readily inflammable material is in the vicinity of the lamps, to prevent escape of sparks of carbon or melted copper. It is recommended that plain carbons, not copper-plated, be used for lamps in such places.

Outside arc lamps should be suspended at least eight feet above sidewalks. Inside arc lamps should be placed out of reach or suitably protected.

Arc lamps, when used in places where they are exposed to flyings or easily inflammable material,

should have the carbons enclosed completely in a tight globe in such manner as to avoid the necessity for spark arresters.

"Enclosed arc" lamps, having tight inner globes, may be used in such places.

Special Wiring for damp places such as breweries, packing houses, stables, dye houses, paper or pulp mills, or buildings specially liable to moisture or acid or other fumes liable to injure the wires or their insulation, except where used for pendants should always be done with approved rubber covered wire, and rigidly supported on porcelain or glass insulators which separate the wires at least one inch from the surface wired over and must be kept apart at least two and one-half inches. The wire in such damp places should contain no splices as it is almost impossible to tape a splice that will prevent acid fumes from getting at the copper surface.

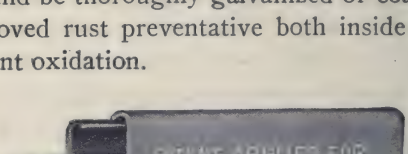
Wood Moulding Work should always be done with approved rubber-covered wire to prevent leakage should the moulding become damp.

This class of work should never be done in concealed or damp places for fear that water may soak into the wood and cause leakage of current between the wires, burning the wood and starting a fire. The action of the current in a case like this is to very gradually convert the wood into charcoal, then dry the water out and ignite the charcoal thus formed. Great care should be observed in driving nails into moulding in order to avoid puncturing the insulation, and possibly grounding the circuit in a way that would not only be difficult to locate, but might

cause a concealed fire back of the plastering or wood work to which the moulding is attached.

Wood Moulding should be made of hard wood and should be made of two pieces, a backing and capping, so constructed as to thoroughly encase the wire. It should provide a one-half inch tongue between the conductors and a solid backing, which under the grooves should not be less than three-eighths of an inch and on the sides not less than one-fourth of an inch in thickness and be able to give suitable protection from abrasion.

Metal Moulding should be of approved make, should be constructed of iron or steel with backing at least .050 inch in thickness, and with capping not less than .040 inch in thickness, and so constructed that when in place the raceway will be entirely closed, and be thoroughly galvanized or coated with an approved rust preventative both inside and out to prevent oxidation.



National Metal Molding.

Elbows, couplings and all other similar fittings should be constructed of at least the same thickness and quality of metal as the moulding itself, and so designed that they will both electrically and mechanically secure the different sections together and maintain the continuity of the raceway. The interior surfaces should be free from burrs or sharp corners which might cause abrasion of the wire coverings.

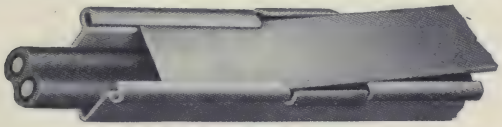
All outlets should be so arranged that the conductors cannot come in contact with the edges of the metal, either of capping or backing. Specially designed fittings which will interpose substantial bar-

riers between conductors and the edges of metal are recommended.

When backing is secured in position by screws or bolts from the inside of the raceway, depressions should be provided to render the heads of the fastenings flush with the moulding.

Metal mouldings should be used only for exposed work, should not be used for circuits requiring more than 660 watts of energy, and should be so constructed as to form an open raceway to be closed by the capping or cover after the wires are laid in.

No moulding work, with either metal or wood, should ever be done in damp or concealed places, or when the difference of potential between any two wires in the same moulding is over 300 volts; metal mouldings should not be used for circuits requiring more than 660 watts of energy. Alternating current circuits should have their two or more wires run in the same metal moulding for inductive reasons.



"Lutz" Metal Molding.

Concealed Wiring or that which is to be run between walls and floors and through joists, should always be done with approved rubber-covered wire, and should be rigidly supported on porcelain or glass insulators which will separate the wires at least one inch from the surface wired over, and the wires kept at least five inches apart, and where it is possible wires should be run singly on separate timbers or joists. The following is a list of approved flexible

conduits: — "Alphaduct," "Braiduct," "Circular Loom," "Flexduct" and "Wireduct."

The wires should be separated from contact with the walls, floor timbers and partitions through which they may pass by non-combustible, non-absorptive insulating tubes, such as glass or porcelain.

Rigid supporting requires, under ordinary conditions, where wiring along flat surface, supports at least every four and one-half feet. If the wires are liable to be disturbed the distance between supports should be shortened.

At distributing centers, outlets or switches where space is limited and the five-inch separations cannot be maintained, each wire must be separately encased in a continuous length of approved flexible tubing.

Wires passing through timbers at the bottom of plastered partitions should be protected by an additional tube extending at least four inches above the timber.

When in a concealed knob and tube system, it is impracticable to place the whole of a circuit on non-combustible supports of glass or porcelain, that portion of the circuit which cannot be so supported should be installed with *approved* metal conduit, or *approved* armored cable except that if the difference of potential between the wires is not over 300 volts, and if the wires are not exposed to moisture, they may be fished if separately encased in approved flexible tubing, extending in continuous lengths from porcelain support to porcelain support, from porcelain support to outlet, or from outlet to outlet.

Wires should at all outlets, except where conduit

is used, be protected by *approved* flexible insulating tubing, extending in continuous lengths from the last porcelain support to at least one inch beyond the outlet. In the case of combination fixtures the tubes should extend at least flush with outer end of gas cap.

It is recommended but not required that *approved* outlet boxes or plates be installed at all outlets in

Approved Insulated Metal Conduit.

concealed "knob and tube" work, the wires to be protected by *approved* flexible insulating conduit, extending in continuous lengths from the last porcelain support into the box.

Insulated Metal Conduits—(Specifications) The metal covering or pipe should be of sufficient thickness to resist penetration by nails, etc., or the same thickness as ordinary gas pipe of the same size.

They should not be seriously affected externally by burning out a wire inside the tube when the iron pipe is connected to one side of the circuit.

The insulating lining should be firmly attached to the pipe, and should not crack or break when a length of conduit is uniformly bent at a temperature of 212 degrees Fahrenheit, to an angle of 90 degrees, with a curve having a radius of 15 inches, for pipes of one inch or less, and fifteen times the diameter of the pipe for larger sizes.

The insulating lining should not soften injuriously at a temperature below 212 degrees Fahren-

heit, and should leave water in which it has been boiled practically neutral.

The insulating lining should be at least one-thirty-second of an inch in thickness, and the materials of which it is composed should be of such a nature as will not have a deteriorating effect on the insulation of the conductor, and be sufficiently tough and tenacious to withstand the abrasion test of drawing in and out of some long lengths of conductors.

The insulating lining should not be mechanically weak after three days' submersion in water, and, when removed from the pipe entire, should not absorb more than ten per cent. of its weight of water during 100 hours of submersion.

All elbows should be made for the purpose, and not bent from lengths of pipes. The radius of the curve of the inner edge of any elbow should not be less than three and one-half inches.

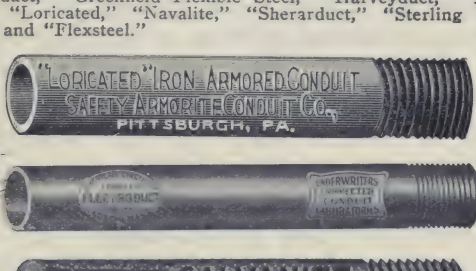
There should not be more than the equivalent of four quarter bends from outlet to outlet, the bends at outlets not being counted.

Each length of conduit, whether insulated or uninsulated should have the maker's name, initials or trade mark stamped in the metal or attached to it in some satisfactory manner, so that it may be readily seen, and thus possible to place the responsibility for pieces not up to standard. The approved make of insulated metal conduit is "Sprague."

Uninsulated Metal Conduits or plain iron or steel pipes may be used instead of the insulated metal conduits, if made equally as strong and thick as the ordinary form of gas pipe of the same size, provided their interior surfaces are smooth and free from

burrs. The pipe should be galvanized, or the inner surfaces coated or enameled to prevent oxidization with some substance which will not soften, so as to become sticky and prevent the wire from being withdrawn from the pipe. Elbows must be made for the purpose and not bent from lengths of pipe. The radius of curves and number of bends from outlet to outlet should be the same as given under Insulated Metal Conduits.

The recommended makes of uninsulated metal conduits are as follows: "American," "Armorduct," "Economy," "Electroduct," "Galvaduct," "Greenfield Flexible Steel," "Harveyduct," "Interiorduct," "Loricated," "Navalite," "Sherarduct," "Sterling Flexible Steel" and "Flexsteel."



Approved Uninsulated Metal Conduits.

This bare iron or steel pipe should never contain any but a special extra insulated wire as described under the following heading:

Conduit Wire for Insulated Metal Conduit, whether single or twin conductors, should be standard rubber-covered wire as described on page 64, and where concentric wire is used in Insulated Metal Conduits, it should have a braided covering between the outer conductor and the insulation of the inner conductor, and, in addition should comply with and be able to withstand the test of standard rubber-covered wire.

Conduit Wire for Uninsulated Metal Conduits should not only have a standard rubber insulation as required for Insulated Metal Conduits, but in

addition should have a second outer fibrous braid of at least one-thirty-second of an inch in thickness, and sufficiently tenacious to withstand the abrasion of being hauled through the metal conduit. When concentric conductors are to be used in uninsulated metal conduits they should not only comply with the requirements when used in insulated metal conduits, but in addition should also have a second outer fibrous covering at least one-thirty-second of an inch in thickness and sufficiently tenacious to withstand the abrasion of being hauled through the metal conduit. The tape or braid required around each conductor for this class of work is intended to hold the rubber insulation in place and prevent jamming and flattening. All such braids should be properly saturated with a preservative compound.

Interior Conduit Installation. All conduits should be continuous from one junction box to another, or to fixtures, and the conduit tube should properly enter all fittings, otherwise the conductors are not perfectly protected, and water is much more liable to gain an entrance into the conduit. No conduit with an inside diameter of less than five-eighths of an inch should be used.

The entire conduit system for a building should be completely installed before a single wire is drawn in, and all ends of conduits should be firmly secured to their terminal fittings, junction boxes, outlet boxes, plates or "condulets." (See p. 119.)

The metal of every conduit system should be effectually and permanently grounded. The conduit is likely to be more or less grounded, and a positive

ground is necessary for the same reason that a positive ground is required for generator frames when it is impossible to perfectly insulate them.

Conduit Wiring. The reason why standard rubber covered wire, and not weatherproof, should be used in conduits, is that the best possible insulation is desirable for this class of work, as the insulating lining of the conduit may be defective in places, and there is possibility of dampness getting into the conduit.

No wires should be drawn in until all mechanical work on the building is done.

Circuits of different systems should not be drawn in the same conduit.

For alternating systems, the two or more wires of a circuit should be drawn in the same conduit in order to avoid trouble from inductive losses, which, under certain conditions, would cause a heating of the iron conduit to a dangerous degree. This and other troubles from induction become very much less if the wires are in the same conduit.

In case of service connections and main runs, this involves running each conduit continuously into a main cut-out cabinet or gutter, surrounding the panel board, as the case may be.

Outlet plates should not be used where it is practicable to install outlet boxes.

The outlet box or plate should be so installed that it will be flush with the finished surface, and if this surface is broken it should be repaired so that it will not show any gaps or open spaces around the edge of the outlet box or plate.

In buildings already constructed where the condi-

tions are such that neither outlet box nor plate can be installed, these appliances may be omitted by special permission of the Inspection Department having jurisdiction, providing the conduit ends are bushed and secured.

Metal conduits where they enter junction boxes, and at all other outlets, etc., should be provided with *approved* bushings fitted so as to protect wire from abrasion, except when such protection is obtained by the use of *approved* nipples, properly fitted in boxes or devices.

Even in direct current work it is advisable to place the two or more wires of a circuit in the same conduit, as in so doing the direct current may be changed for the alternating current without the necessity of re-wiring, which would be necessary if only a single wire were placed in a conduit just large enough to accommodate it.

Conductors in vertical conduit risers should be supported within the conduit system in accordance with the following table:—

No. 14 to 0 every 100 feet.
No. 00 to 0000 every 80 feet.
0000 to 350,000 C. M. every 60 feet.
350,000 C. M. to 500,000 C. M. every 50 feet.
500,000 C. M. to 750,000 C. M. every 40 feet.
750,000 C. M. every 35 feet.

A turn of 90 degrees in the conduit system will constitute a satisfactory support, as per above table.

The following methods of supporting cables are recommended:—

1. Junction boxes may be inserted in the conduit system at the required intervals, in which insulating

supports of *approved* type must be installed and secured in a satisfactory manner so as to withstand the weight of the conductors attached thereto, the boxes to be provided with proper covers.

2. Cables may be supported in *approved* junction boxes on two or more insulating supports so placed that the conductors will be deflected at an angle of not less than 90 degrees, and carried a distance of not less than twice the diameter of the cable from its vertical position. Cables so suspended may be additionally secured to these insulators by tie wires.

Fixtures should, when supported from the gas piping of a building, be insulated from the gas pipe system by means of approved insulating joints (see page 96) placed as close as possible to the ceiling, and the wires near the gas pipe above the insulating joint should be protected from possible contact by the use of porcelain tubes.

All burrs or fins should be removed from the fixtures before the wires are drawn in. The tendency to condensation within the pipes should be guarded against by sealing the upper end of the fixture.

In combination fixtures, where the wiring is concealed between the inside pipe and outer casing, the space between pipe and casing should be at least a quarter of an inch to allow plenty of room for the insulation of the wires without jamming.

Fixtures should be tested for "contacts" between conductors and fixtures, for "short-circuits" and for ground connections before it is connected to its supply conductors.

Ceiling blocks of fixtures should be made of insulating material; if not, the wires in passing through

the plate should be surrounded by porcelain tubes, which should extend below the insulating joint.

When fixtures have canopies against plaster in fireproof buildings, or where wire lath or metal ceiling or metal wall finish is used, the canopies should be thoroughly and permanently insulated from such walls or ceilings by approved canopy insulators. See illustration on page 96.

Rosettes. These fittings should not be located where inflammable flyings or dust will accumulate on them. Bases should be high enough to keep the wires and terminals at least one-half inch from the surface to which the rosette is attached.

Terminals with a turned up lug to hold the wire or cord shrould be used, and in no case must the wire be cut or injured. Fused rosettes are not advised for use where cords can be properly protected by line cut-outs, and where necessary those equipped with *enclosed* fuses are recommended. If fused rosettes are used the next fuses back should not be over 25 amperes capacity.

Fixture Wiring should be done with approved fixture wire, either solid or stranded, which has a solid insulation with a slow-burning, tough, outer covering, the whole at least one-thirty-second of an inch in thickness, and having an insulation resistance between conductors, and between either conductor and the ground, of at least one megohm per mile. The voltage should never exceed 300 on wires in fixtures.

Although No. 18 (B. & S. gauge) is allowable in fixture work, it is never advisable to use smaller than No. 16 for mechanical reasons. Supply con-

ductors, and especially the splices to fixture wires, should be kept clear of the grounded part of gas pipes, and where shells are used the latter should have area enough to prevent pressing the wires against the gas pipe when finally in place. Where fixtures are wired on the outside it is advisable to use cord for attaching the wires to the fixture, and not short bits of wire, as the latter might produce a short circuit or ground.

Flexible Cord should be made of stranded copper conductors, no single strand should be larger than No. 26 or smaller than No. 30 (B. & S. gauge) and each conductor should be covered by an approved insulation and be protected from mechanical injury by a tough braided outer covering. When used for pendant lamps it should hang freely in air and so placed that there is no chance of its coming in contact with anything excepting the lamp socket to which it is attached and the rosette from which it hangs. Each stranded conductor should have a carrying capacity equivalent to not less than a No. 18 (B. & S. gauge) wire. The covering of the stranded wires for flexible cord should first have a tight, close wind of fine cotton, which is intended to prevent any broken strand from piercing the insulation and causing a short circuit or ground. Secondly it should have a solid waterproof insulation at least one-thirty-second of an inch thick and should show an insulation resistance of 50 megohms per mile throughout two weeks' submersion in water at 70 degrees Fahrenheit. The outer protecting braiding should be so put on and sealed in place that when cut it will not fray out.

Approved flexible cord may be had from any of the makers mentioned on pages 64 and 65.

Flexible cord should not be used as a support for clusters, as it is not strong enough, and it should never be used for anything other than pendants, wiring of fixtures and portable lamps, portable motors or small light electrical apparatus. Where used for "portables" it should have a special outer covering.

Flexible cord should never be used in show windows, as a defective piece might cause a short circuit and set fire to flimsy material or decorations. Many fires have been caused by the use of flexible cord in show windows, where handkerchiefs, decorations, etc., have been pinned to the cord. When the current is "turned on" short circuits are caused by the pins, and a fire is the result. But the steel-armored Flexible Cords made by the Sprague Electric Company and the National Metal Molding Company are permitted.

Insulating bushings should be used where cords enter lamp sockets and desk stand lamps.

Flexible cord should be so suspended that the entire weight of the socket, lamp and shade will be borne by knots under the bushing in the socket, and above the point where the cord comes through the ceiling block or rosette, in order that the strain may be taken from the joints and binding screws. It is good practice to always solder the ends of flexible cords which are going under binding screws, as it holds the strands together and prevents the pressure of the screws from forcing the strands from under them, and against the shell of the socket, causing a ground shell, or short circuit.

Where it becomes necessary to solder a great number of ends, as may be required when wiring a factory, use a small pot of melted solder and dip the ends of the wire, which have all been previously cut to the proper length and fluxed with a good soldering paste or solution.

Standard Lamp Sockets should be plainly marked fifty candle-power, 250 volts, or 250 w., 250 v., and

Waterproof Keyless Socket to be used in dye houses and damp places.

with either the manufacturer's name or registered trade mark. The inside of the shell of the socket should have an insulating lining which should absolutely prevent the shell from becoming a part of the circuit even though a wire or strand inside the socket should become loose or come out from under a binding screw. This insulating lining should be at least one-thirty-second of an inch thick and of a tough and tenacious material.

Special Lamp Sockets. In rooms where inflammable gases may exist, both the socket and lamp

should be enclosed in a vapor-tight globe and supported on a pipe-hanger and wired with "Rubber-Covered" wire, soldered directly to the circuit. No fuses or switches of any sort should be used in the room in such cases as the slightest arc might produce dangerous explosions or fires.

In damp or wet places, such as dye houses breweries, etc., a water-proof socket such as shown on page 91, should be used. Water-proof sockets should be hung by separate stranded rubber-covered wires, not smaller than No. 14 (B. & S.). These wires should be soldered direct to the circuit wires, but supported independently of them. All sockets for the above conditions should be keyless

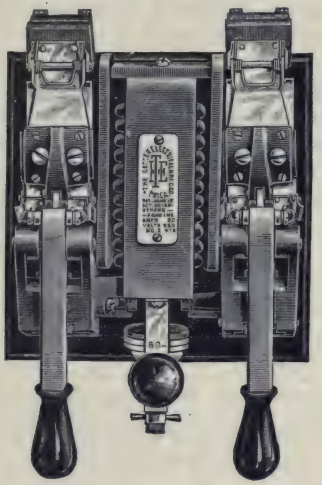
Splicing should be done as described on page 39, in fact all wires, for this class of work, should be joined in this thorough manner and soldered.

Stranded Wires in every case should be soldered together before being clamped under binding screws, and when they have a conductivity greater than No. 10 (B. & S.) copper wire, they should be soldered into lugs. Stranded wires if not thus stiffened before being clamped under binding posts are liable to be pressed out or easily worked loose making a poor contact, which causes heating, a possibility of arcing or a complete burn out. Dossert approved solderless lugs may be used.

Automatic Cut-Outs such as circuit breakers and fuses should be placed on all service wires as near as possible to the point where they enter the building, on the inside of the walls, and arranged to cut off the entire current from the building.

The cut-out or circuit breaker should always be

the first thing that the service wires are connected to after entering the building; the switch next, and then the other fixtures or devices in their order. This arrangement is made so that the cut-out or circuit-breaker will protect all wiring in the building, and the opening of the switch will disconnect all the wiring. (See cuts on pages 32-37.)



Circuit Breaker.

These automatic cut-outs should not, however, be placed in the immediate vicinity of easily ignitible stuff, or where exposed to inflammable gases or dust, or to flyings of combustible material, as the arcing produced whenever they break the circuit might cause a fire or explosion. When they are exposed to dampness they should be inclosed in a waterproof box or mounted on porcelain knobs.

All cut-outs and circuit-breakers should be supported on bases of non-combustible non-absorptive insulating material. Link fuses should never be used, they are obsolete and have been the cause of no end of fires and troubles. Enclosed fuses are always preferable.

Cut-outs should operate successfully under the most severe conditions they are liable to meet with in practice, on short circuits with fuses rated at 50 per cent. above, and with a voltage 25 per cent. above the current and voltage for which they are designed. Circuit breakers should also be designed to successfully operate under the severe conditions liable to be met with in practice, and when designed to carry less than 100 amperes must be able to operate successfully on a short circuit with a supply system having a capacity of 1,000 amperes. They must also stand 2,000 volts A. C. for one minute between ground and live metal parts. All cut-outs and circuit breakers should be plainly marked, and where it will always be visible, with the name of the maker, and current and voltage for which the device is designed.

Cut-outs or circuit breakers should be placed at every point where a change is made in the size of wire, unless such a device in the larger wire will protect the smaller. They should never be placed in canopies or shells of fixtures, but should be so placed that no set of incandescent lamps, whether grouped on one fixture or several fixtures or pendants, requiring more than 660 watts should be dependent upon one cut-out. Special permission may be given in writing by the Inspection Department having jurisdiction in case extra large or special chandeliers are to be used. Fuses for cut-outs should not have a capacity to exceed the carry-

ing capacity of the wire, and where circuit breakers are used they should not be set more than 30 per cent. above the allowable carrying capacity of the wire, unless a fusible cut-out is also installed in the circuit as shown in the illustration on page 33 Excepting on main switchboards, or where they are at all times subject to expert supervision, circuit breakers should never be used as a protection to a circuit without the additional use of enclosed fuse cut-outs.

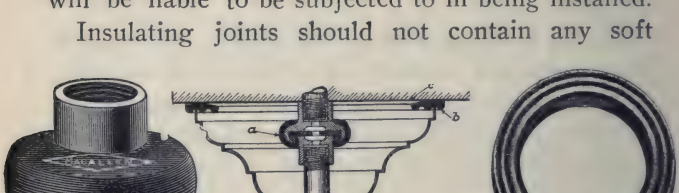
Circuit breakers open at exactly the current they are set for and instantly, therefore it is necessary to set them considerably above the ordinary amount of current required to keep them from constantly opening on slight fluctuations. When this is the case a double-pole fusible cut-out should be added to protect the wire from a heavy, steady current, which may be maintained just below the opening point of the circuit breaker. The fuse requires a little time to heat, and would not therefore blow out with a momentary rise of current which might open the circuit breaker if set as low as necessary to protect the wire, which may be of a size only large enough for the figured amount of current under ordinary conditions of operation. If, however, in the case of motor-wiring, the size of wire is 25 per cent. above the figured size for the motor's average current, as it should be, then the introduction of a fusible cut-out in addition to the circuit breaker is unnecessary, as is shown in the illustration on page 34.

Insulating Joints should be made entirely of material that will resist the action of illuminating

gases, and will not give way or soften under the heat of an ordinary gas flame, or leak under a moderate pressure and able to withstand 4,000 volts for five minutes.

They should be so arranged that a deposit of moisture will not destroy the insulating effect, and should have an insulation resistance of at least 250,000 ohms between the gas pipe attachments, and be sufficiently strong to resist the strain they will be liable to be subjected to in being installed.

Insulating joints should not contain any soft



A B C

A Macalen Insulating Joint. B Macallen Canopy and Insulating Joint in Position. C Macallen Canopy Insulator.

rubber in their composition. The insulating material should be of some hard and durable material such as mica.

Insulating Resistance. The wiring in any building should test free from grounds, *i. e.*, the complete installation should have an insulation between conductors and between all conductors and the ground (not including attachments, sockets, receptacles, etc.) of not less than the following:

Up to	5	amperes.....	4,000,000 ohms
"	10	"	2,000,000 "
"	25	"	800,000 "

Up to	50 amperes	400,000	ohms.
"	100 "	200,000	"
"	200 "	100,000	"
"	400 "	50,000	"
"	800 "	25,000	"
"	1,600 " and over..	12,500	"

All cut-outs and safety devices in place in the above when the tests are made.

Where lamp sockets, receptacles and electroliers, etc., are connected, one-half of the above will be sufficient. (See page 50 for method.)

Knife Switches — (Specifications). Hinges of knife switches should not be used to carry current unless they are equipped with spring washers, held by locked nuts or pins so arranged that a firm and secure connection will be maintained at all positions of the switch blades and unless they are connected in circuit so that the blades will not be alive when the switch is open.

The bases of all switches should be made of non-combustible, non-absorptive insulating material, such as slate, marble or porcelain.

Switches for currents of over 25 amperes should be equipped with lugs firmly screwed or bolted to the switch and into which the conducting wires should be soldered. For the smaller sized switches simple screws can be employed provided they are heavy enough to stand considerable hard usage. Holes for inserting screws for supporting the switch should not be placed between contacts of opposite polarity.

Pieces carrying the contact jaws should be secured to the base by at least two screws or else made with a square shoulder or equipped with dowel pins to prevent possible turnings and the nuts or screw heads on the under side of the base should be countersunk not less than one-eighth inch and covered with a waterproof compound which will not melt below 150 degrees Fahrenheit.

All cross-bars less than three inches in length should be made of insulating material. Bars of three inches and over which are made of metal to insure greater mechanical strength should be sufficiently separated from the jaws of the switch to prevent arcs following from the contacts to the bar on the opening of the switch under any circumstances. Metal bars should preferably be covered with insulating material.

All switches should have ample metal for stiffness and to prevent rise in temperature of any part of over 50 degrees Fahrenheit at full load, the contacts being arranged so that a thoroughly good bearing at every point is obtained with contact surfaces advised for pure copper blades of about one square inch for each 50 amperes; the whole device should be mechanically well made throughout.

The following table shows minimum break distances and separation of nearest metal parts of opposite polarity for different voltages and different currents. The values given are correct for switches to be used on direct current systems and can therefore be safely followed in devices designed for alternating currents.

125 VOLTS OR LESS:	Minimum Separation of Nearest Metal Parts of Opposite Polarity.	Minimum Break-Distance.
For Switchboards and Panel Boards:—		
10 amperes or less	¾ inch	½ inch.
11-30 amperes	1 "	¾ "
31-50 "	1¼ "	1 "
For Individual Switches:—		
10 amperes or less	1 inch	¾ inch.
11-30 amperes	1¼ "	1 "
31-100 "	1½ "	1¼ "
101-300 "	2¼ "	2 "
301-600 "	2¾ "	2½ "
601-1000 "	3 "	2¾ "

126 to 250 VOLTS:		
For all Switches:—		
10 amperes or less	1½ inch	1¼ inch.
11-30 amperes	1¾ "	1½ "
31-100 "	2¼ "	2 "
101-300 "	2½ "	2¼ "
301-600 "	2¾ "	2½ "
601-1000 "	3 "	2¾ "

For 100 ampere switches and larger, the above spacings for 250 volts direct current are also approved for 500 volts alternating current. Switches with these spacings intended for use on alternating-current systems with voltage above 250 volts must be stamped with the voltage for which they are designed, followed by the letters "A. C."

251 TO 600 VOLTS:		
For all Switches:—		
10 amperes of less	3½ inch	3 inch.
11-35 amperes	4 "	3½ "
36-100 "	4½ "	4 "

Auxiliary breaks or the equivalent are recommended for switches designed for over 300 volts and less than 100 amperes, and will be required on switches designed *for use in breaking currents* greater than 100 amperes at a pressure of more than 300 volts.

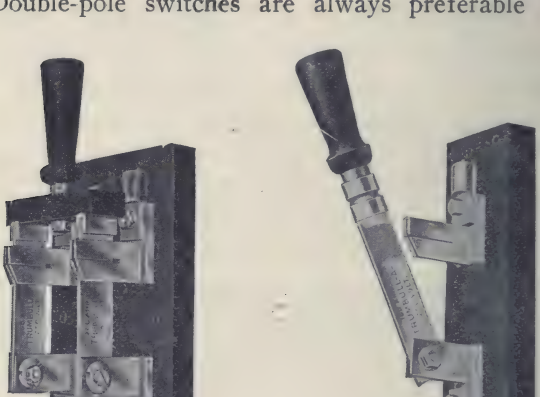
For three-wire Edison systems the separations and break distances for plain three-pole knife-switches must not be less than those required in the above table for switches designed for the voltage between the neutral and outside wires.

Knife Switches—(Installation). Switches should be placed on all service wires, either overhead or underground, in a readily accessible place, as near as possible to the point where the wires enter the building.

Knife switches should always be installed so that the handle will be *up* when the circuit is closed,

so built and arranged to cut off the entire current, that gravity will tend to open rather than close the switch. They should never be single pole except when the circuit which they control is carrying not more than six 16-candle-power lamps or their equivalent.

Double-pole switches are always preferable to



An Approved Double Pole and Single-Pole Knife Switch. Always install so that the handle will be *up* when circuit is closed.

single-pole, as they absolutely disconnect the part of the circuit out of use.

Flush Switches. Where gangs of flush switches are used, whether with conduit systems or not, the switches should be enclosed in boxes constructed of, or lined with, fire-resisting material.

Where two or more switches are placed under one plate, the box should have a separate compartment for each switch. No push buttons for bells,

gas-lighting circuits, or the like, should be placed in the same wall plate with switches controlling electric light or power wiring.

Snap Switches like knife switches, should always be mounted on non-combustible, non-absorptive insulating bases, such as slate or porcelain, and should have carrying capacity sufficient to prevent undue heating.

When used for service switches they should indicate at sight whether the current be "on" or "off." Indicating switches should be used for all work to prevent mistakes and possible accidents. The fact that lights do not burn or the motor does not run is not necessarily a sure sign that the current is off.

Every switch, like every other piece of electrical apparatus, should be plainly marked where it is always visible with the maker's name and the current and voltage for which it is designed.

On constant potential systems, these switches, like knife switches, should operate successfully at 50 per cent. overload in amperes with 25 per cent. excessive voltage under the most severe conditions they are likely to meet with in practice. They should have a firm contact, should make and break readily, and not stop when motion has once been imparted to the handle.

On constant current systems, they should close the main circuit and disconnect the branch wires when turned "off"; should be so constructed that they will be automatic in action, not stopping between points when started and should prevent an arc between the points under all circumstances

INCANDESCENT LAMP DATA

CARBON LAMPS

Volts	Watts	C. P.	W. P. C.	Amps.	Hot Res.
52	10	2.0	5.00	0.192	271.00
"	25	8.1	3.06	0.481	108.40
"	30	9.3	3.23	0.577	90.20
"	50	16.6	3.01	0.962	54.10
"	60	19.6	3.06	1.154	45.08
"	100	33.2	3.01	1.925	27.02
"	120	37.1	3.24	2.301	22.50
104	10	2.0	5.00	0.096	1084.00
"	20	4.8	4.15	0.192	542.00
"	25	8.1	3.10	0 240	433.50
"	30	9.3	3.23	0.288	361.00
"	50	16.8	2.97	0.481	216.20
"	60	20.2	2.97	0.577	180.40
"	100	33 6	2.97	0.962	108.20
"	120	40.4	2.97	1.154	90.20
110	10	2.0	5.00	0.091	1210.00
"	20	4.8	4.15	0.182	605.00
"	25	8.1	3.10	0.227	485.00
"	30	9 3	3.23	0.273	403.00
"	50	16.8	2.97	0.455	242.00
"	60	20.2	2.97	0 546	201.80
"	100	33.6	2.97	0.910	121.00
"	120	40.4	2.97	1.091	100 80
220	35	8.0	4.40	0.159	1382
"	60	16.3	3.69	0.273	806
"	120	32.5	3.69	0.547	403

GEM LAMPS

Volts	Watts	C. P.	W. P. C.	Amps.	Hot Res.
110	40	15.6	2.56	0.364	302.0
"	50	20 0	2.50	0.455	242.0
"	60	24 0	2.50	0.546	201.5
"	80	32.5	2.46	0.727	151.4
"	100	40.7	2.46	0.909	121.0
"	125	50 8	2.46	1.136	96.8
"	187.5	76.2	2.46	1.705	64.5
"	250	101.6	2.46	2.272	48.4
115	40	15.6	2.56	0.348	331.0
"	50	20.0	2.50	0.435	264.5
"	60	24.0	2.50	0 522	220.4
"	80	32.5	2.46	0.696	165.4
"	100	40.7	2.46	0.870	132.2
"	125	50.8	2.46	1.087	105.9
"	187.5	76.2	2.46	1.630	70.6
"	250	101.6	2.46	2.174	52.9

TANTALUM LAMPS

Volts	Watts	C. P.	W. P. C.	Amps.	Hot Res.
110	25	12.7	1.97	0 228	482.0
"	40	22.3	1.79	0.364	302.0
"	50	27.9	1.79	0.455	242.0
"	80	44.6	1.79	0.727	151.4

TANTALUM LAMPS.—Continued

Volts	Watts	C. P.	W. P. C.	Amps.	Hot Res.
115	25	12.7	1.97	0.218	528.0
"	40	22.3	1.79	0.348	331.0
"	50	27.9	1.79	0.435	264.5
"	80	44.6	1.79	0.695	165.5
220	50	25.4	1.97	0.227	970.0
"	80	40.6	1.97	0.364	605.0

MAZDA LAMPS

Volts	Watts	C. P.	W. P. C.	Amps.	Hot Res.
110	25	19.10	1.31	0.228	482.0
"	40	32.50	1.23	0.364	302.0
"	60	50.80	1.18	0 546	201.5
"	100	84.70	1.18	0.909	121.0
"	150	127.00	1 18	1.364	80.7
"	250	222.00	1.13	2.272	48.4
"	400	354.00	1.13	3.640	30.2
"	500	442.00	1.13	4.550	24.2
115	25	19.10	1.31	0.218	528.0
"	40	32.50	1.23	0 348	331.0
"	60	50.80	1.18	0.522	220.4
"	100	84.70	1.18	0.870	132 2
"	150	127.00	1 18	1.305	88.2
"	250	222 00	1.13	2.174	52.9
"	400	354.00	1.13	3.48	33 0
"	500	442.00	1.13	4.350	26.4
220	45	30.4	1.48	0.204	1078
"	60	40.5	1.48	0.273	807
"	100	67.6	1.48	0.455	484
"	150	101.4	1.48	0 681	323
"	500	407.0	1.23	2.272	96.7

COOPER HEWITT LAMP UNITS—DIRECT CURRENT

Type	Watts	Length of tubes, ins.	Candle power	Watts per candle.
H	192	21"	300	.64
Double H	385	2-21" ea.	600	.64
K	385	45"	700	.55
P	385	50"	800	.48

ALTERNATING CURRENT (60-cycle, 95-125 volts)

F	400-520	50"	750-900	.53-.58

Power Factor 70%.

The tables below show the variation in the life and candle-power of incandescent lamps with various percentages of decrease and increase of rated voltage:

CARBON FILAMENT LAMP VARIATIONS.

	% Volts	% C. P.	% Amperes	% Ohms	% Watts	% W. P. C.	% Life
	10	69.8	10.8		21.9	28.2	85.5
	9	61.4	9.7		19.5	25.9	82.6
	8	53 4	8.5		17.2	23.5	79.0
Increase	7	45.6	7.5		15.0	21.0	74.6
	6	38.2	6.4		12.8	18.4	69.3
	5	31.1	5.4		10.6	15.7	62.7
	4	24.3	4.2		8.4	12.8	54.8
	3	17.9	3.2		6.3	9.8	45.1
	2	11.6	2.1		4.2	6.7	33.1
	1	5.7	1.2		2.1	3.4	18.5
	Normal	0	0		0	0	0
	1	5.4	1.2		2.1	3.6	22.5
	2	10.6	2.1		4.1	7.3	50.5
	3	15.5	3.2		6.1	11.2	85.3
	4	20 3	4.2		8.1	15.3	128 9
	5	24.8	5.4		10.1	19.6	180.0
	6	29 0	6 4		12.0	24.1	250.4
	7	33.2	7.4		13.9	28.8	336.0
	8	37.1	8.4		15.8	33.8	442.0
	9	40.7	9.5		17.7	39.0	578.0
	10	44.3	10.7		19.6	44.4	747 0

Decrease: Decrease (% C. P.), Decrease (% Amperes), Decr (% Watts), Increase (% W. P. C.), Increase (% Life)

Practically Constant (% Ohms)

METAL FILAMENT LAMP VARIATIONS

	% Change in Voltage	% C. P. Mazda	% Watts Mazda	% C. P. Tantalum	% Watts Tantalum	% C. P. Gem	% Watts Gem
	10	42.1	16 4	49.2	17.8	58.0	18.4
	9	37.4	14.7	43.6	15.9	51.3	16.5
	8	32.8	13.0	38.1	14.1	44.7	14.6
	7	28 3	11.3	32.9	12.3	38.4	12.7
	6	23.9	9.6	27.8	10.5	32.3	10.8
Increase	5	19.7	8.0	22.7	8.7	26.4	9.0
	4	15.5	6.4	17.8	6.9	20.7	7.2
	3	11.5	4.8	13.2	5.1	15.2	5.4
	2	7.6	3.2	8.7	3.4	10.0	3.6
	1	3.7	1.6	4.3	1.7	4.9	1.8
	Normal	0	0	0	0	0	0
	1	3.7	1.6	4.2	1.7	4.7	1.8
	2	7.2	3.2	8.3	3.4	9.3	3.6
	3	10.6	4.8	12.0	5.1	13.6	5.3
	4	13.9	6.4	15.8	6.8	17.8	7 0
	5	17.2	8.0	19.3	8.5	21.8	8.7
	6	20.4	9.5	22.9	10.1	25.7	10.4
Decrease	7	23.4	11.0	26.3	11.7	29.4	12.1
	8	26.4	12.5	29.5	13.3	33.0	13.8
	9	29.3	14.0	32.7	14.9	36.4	15.5
	10	32.2	15.5	35.8	16.5	39.7	17.1

Increase: Increase (% C. P.), Increase (% Watts), Increase (% Tantalum), Increase (% Watts Tantalum), Increase (% C. P. Gem), Increase (% Watts Gem)

Decrease: Decrease (% C. P. Mazda), Decrease (% Watts Mazda), Decrease (% C. P. Tantalum), Decrease (% Watts Tantalum), Decrease (% C. P. Gem), Decrease (% Watts Gem)

The illumination given by one candle at a distance of one foot is called the "candle-foot" and is taken as a unit of intensity. In general, intensity of illumination should nowhere be less than one candle-foot, and the demand for light at the present time quite frequently raises the brilliancy to double this amount. As the intensity of light varies inversely with the square of the distance, a 16-candle-power lamp gives a candle-foot of light at a distance of four feet. A candle-foot of light is a good intensity for reading purposes.

Assuming the 16-candle-power lamp as the standard, it is generally found that two 16-candle-power lamps per 100 square feet of floor space give good illumination, three very bright, and four brilliant. These general figures will be modified by the height of ceiling, color of walls and ceiling, and other local conditions. The lighting effect is reduced, of course, by an increased height of ceiling. A room with dark walls requires nearly three times as many lights for the same illumination as a room with walls painted white. With the amount of intense light available in arc and incandescent lighting, there is danger of exceeding "the limits of effective illumination and producing a glaring intensity," which should be avoided as carefully as too little intensity of illumination.

DISTRIBUTION considers the arrangement of the various sources of light and the determination of their candle-power. The object should be to "secure a uniform brilliancy on a certain plane, or within a given space. A room uniformly lighted, even though comparatively dim, gives an effect of much better illumination than where there is great brilliancy at some points and comparative darkness at others. The darker parts, even though actually light enough, appear dark by contrast, while the lighter parts are dazzling. For this reason naked lights of any kind are to be avoided, since they must appear as dazzling points, in contrast with the general illumination."

THE ARRANGEMENT OF THE LAMPS is dependent very largely upon existing conditions. In factories and shops, lamps should be placed over each machine or bench so as to give the necessary light for each workman. In the lighting of halls, public buildings and large rooms, excellent effects are obtained by dividing the ceilings into squares and placing a lamp in the center of each square. The size of square depends on the height of ceiling and the intensity of illumination desired. Another excellent method consists in placing the lamps in a border along the walls near the ceiling.

For the illumination of show windows and display effects, care must be taken to illuminate by reflected light. The lamps should be so placed as to throw their rays upon the display without casting any direct rays on the observer.

The relative value of high candle-power lamps in place of an equivalent number of 16-candle-power lamps is worthy of notice. Large lamps can be efficiently used for lighting large areas, but in general, a given area will be much less effectively lighted by high candle-power lamps than by an equivalent number of 16-candle-power lamps. For example, sixteen 64-candle-power lamps distributed over a large area will not give as good general illumination as sixty-four 16-candle-power lamps distributed over the same area. High candle-power lamps are chiefly useful when a brilliant light is needed at one point, or where space is limited and an increase in illuminating effect is desired.

THE RELATIVE VALUE OF THE ARC AND INCANDESCENT SYSTEMS OF LIGHTING is frequently difficult to determine. Incandescent lamps have the advantage that they can be distributed so as to avoid the shadows necessarily cast by one single source of light. Arc lamps used indoors with ground or opal globes cutting off half the light, have an efficiency not greater than two or three times that of an incandescent lamp. Nine 50-watt, 16-candle-power lamps consume the same power as one full 450-watt arc lamp. It has been found that unless an area is so large as to require 200 or 300 incandescent lights distributed over it, arc lamps requiring equal total power will not light the area with as uniform brilliancy.

PORCELAIN WIRING DEVICES.

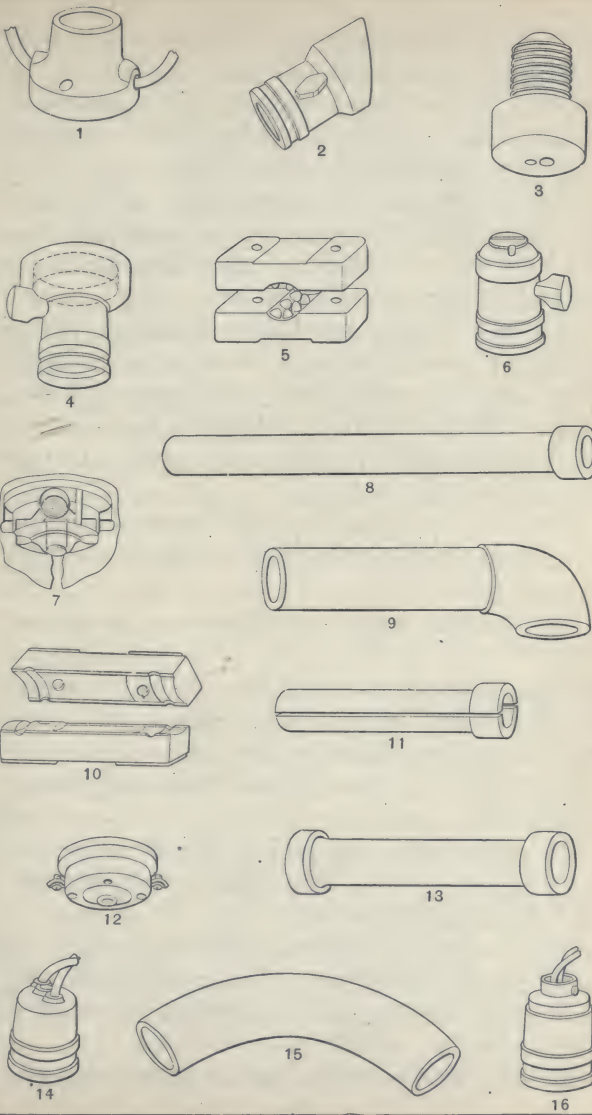
Fig. 1, on page 107, shows weatherproof lamp receptacle to be used in damp places.

Fig. 2 shows a new form of angle socket designed especially for show window work and may be used in either open or concealed wiring.

Fig. 3, an attachment plug for use in carrying flexible cord to portable lamps or fan motors.

Fig. 4 is known as the concealed wall socket for covering holes in plastered walls where the wiring protrudes.

Fig. 5 illustrates a new form of one-wire cleat



Porcelain Wiring Devices.

with projecting teeth in groove to prevent slipping of wire when once rigidly placed in position.

Fig. 6 shows an all porcelain pendant socket.

Fig. 7, a new type of fuseless, cleat rosette for pendant work in offices and factories.

Fig. 8 shows an extra special form of porcelain tube to be used in wiring through brick partitions and walls and are made in lengths up to 24 inches and in diameters up to 3¾ inches.

Fig. 9 shows the proper form of porcelain tubing to be used where wires enter building with the curved portion on the outside and pointing downward, forming a rip loop in the wire, thus preventing rain or moisture from entering the building through the tube.

Fig. 10 shows a standard type of two-wire cleat for ordinary incandescent lamp wiring of this character.

Fig. 11 shows a split tube which may be inserted in partitions or in places where tubing is called for without removing or taking down a job of wiring already installed. They are also suitable for replacing broken tubes without removing the wire.

Fig. 12 shows a simple form of clamp ear, fuseless cleat rosette.

Fig. 13 is a cross over tube to be used where one circuit crosses another, thus keeping wires of opposite polarity rigidly apart.

Fig. 14 shows a weatherproof socket made entirely of porcelain for use in breweries, dye houses or other damp places liable to corrode an ordinary metallic socket.

Fig. 15 shows a special form of curved tube for

use in outlet work to prevent the contact of the circuit wires with metal gas pipe, a pair of these insulators being placed on each side of the gas pipe above the insulating joint which separates the electrical or combination fixture from the main piping.

Fig. 16 is another form of weatherproof socket but which has a brass cap suitable for screwing on to a metal bracket.

Fuses. Enclosed fuses of standard sizes are now on the market and are preferable to link fuses. Where link fuses are used they should have contact surfaces or tips of harder metal, having perfect electrical connection with the fusible part of the strip.

The use of the hard metal tip is to afford a strong mechanical bearing for the screws, clamps, or other devices provided for holding the fuse.

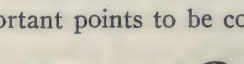
They should be stamped with about 80 per cent. of the maximum current they can carry indefinitely, thus allowing about 25 per cent. overload before the fuse melts.

With naked open fuses, of ordinary shapes, and not over 500 amperes capacity, the *maximum* current which will melt them in about five minutes may be safely taken as the melting point, as the fuse practically reaches its maximum temperature in this time. With larger fuses a longer time is necessary.

Fuses have been known to blow out simply from the heat due to poor contact when nowhere near their current-carrying capacity had been reached. They should be so put up and protected that nothing will tend to rupture them except an excessive flow of current. No fuse of the larger sizes ever blew out without causing a greater or less fire risk.

Fuses blow out or melt from excessive heat and nothing else, and are therefore not as instantaneous in their action as a circuit breaker, which is constantly cared for and kept clean. Central stations or large isolated plants subject to greatly varying loads should have their lines and generators protected by both fuses and magnetic circuit breakers as a double protection against excessive current.

The lengths of fuses and distances between terminals are important points to be considered in the



The above cut illustrates the manner in which harder metal strips should be attached to fuse wire.

proper installation of these electrical "safety valves." No fuse block should have its terminal screws nearer together than one inch on 50 or 100-volt circuits, and one inch additional space should always be allowed between terminals for every 100 volts in excess of this allowance. For example: 200-volt circuits should have their fuse terminals 2 inches apart, 300 volts 3 inches, and 500 volts 5 inches. This rule will prevent the burning of the terminals on all occasions of rupture from maximum current, and this maximum current means a "short circuit." Good contact is absolutely essential in the installation and maintenance of fuses. See that the copper tips to all fuses are well soldered to the fuse wire, and furthermore see that the binding screw or nut is firmly set up against this copper tip when the fuse is placed in circuit; a 100-ampere fuse can be readily "blown" by 25 amperes if the above precautions

are not carried out. Poor contact in every case can cause a heating beyond the carrying capacity of the largest fuses. On the other hand, much damage can be done by using too short fuses and too large terminals, as the radiation of heat from the short piece of fuse wire to the heavy metal terminals and set screws or nuts can very easily raise the current carrying capacity of a fuse designed to carry 50 amperes to 100 amperes, or even more. All open link fuses in every case, should be placed in approved Cut-out Cabinets.

The following table shows the minimum break distance and the separation of the nearest metal parts of opposite polarity for plain open link fuses when mounted on slate or marble bases for different voltages and for different currents:

	Separation of nearest metal parts of opposite polarity.	Minimum break distance.
125 VOLTS OR LESS.		
10 amperes or less	¾ inch	¾ inch.
11—100 amperes	1 "	¾ "
101—300 "	1 "	1 "
125 TO 250 VOLTS.		
10 amperes or less	1½ "	1¼ "
11—100 amperes	1¾ "	1¼ "
101—300 "	2 "	1½ "

Fuse Terminals should be stamped with the maker's name, initials, or some known trade-mark.

Cut-out Cabinets should be so constructed, and cut-outs so arranged, as to obviate any danger of the molten fuse metal coming in contact with any substance which might be ignited thereby.

A suitable box can be made of marble, slate or wood, strongly put together, the door to close against a rabbet so as to be perfectly dust tight, and

it should be hung on strong hinges and held closed by a strong hook or catch. If the box is wood the inside should be lined with slate or with sheets of asbestos board about one-sixteenth of an inch in thickness, neatly put on and firmly secured in place by shellac and tacks. With metal conduit systems the lining of either the box or the gutter should be of one-sixteenth inch galvanized, painted or enameled steel, or preferably one-quarter inch slate or marble.

The object of the lining of such cut-out cabinets or gutters is to render the same approximately fireproof in case of short circuit after the wires leave the protecting metal conduits.

Two thicknesses of 1/32 inch steel may be used instead of one of 1/16 inch.

With wood cabinets the wood should be thoroughly filled and painted before the lining is put in place.

The Enclosed Fuse or "Cartridge Fuse" consists of a fusible strip or wire placed inside of a tubular holding jacket which is filled with porous or powdered insulating material through which the fuse wire is suspended from end to end and which surrounds the fuse wire. The wire, tube and filling are made into one complete self-contained device with brass or copper terminals or ferrules at each end. The fuse wire being soldered to the inside of the ferrules. When an inclosed fuse "blows" by excess current or short circuit the gases resulting are taken up by the filling. Burned out fuses may be returned to their makers for refilling at slight cost.

"D & W" STANDARD FUSES—250-22,000 VOLTS

Volts	Ampere Capacity	Type A Distance on Centres	Type C Length Over all	Knife Blade Contact
250	0-6	$2\frac{9}{16}$″	$2\frac{1}{2}$″	—
250	7-15	$3\frac{1}{16}$	$2\frac{1}{2}$	—
250	16-30	$3\frac{13}{16}$	$2\frac{1}{2}$	—
250	31-60	$4\frac{9}{16}$	$3\frac{5}{8}$	—
250	61-125	$5\frac{13}{16}$	$4\frac{1}{2}$	—
250	126-300	$6\frac{3}{4}$	6	—
250	301-500	$6\frac{3}{4}$	6	—
500	0-10	$5\frac{7}{16}$	—	—
500	11-25	$6\frac{1}{16}$	—	—
500	26-50	$6\frac{3}{4}$	—	—
500	51-125	$7\frac{1}{2}$	—	—
500	126-300	$8\frac{1}{4}$	—	—
500	0-15	—	$4\frac{5}{8}$	—
500	16-30	—	5	—
500	31-60	—	6	—
500	61-125	—	6	—
500	126-300	—	$6\frac{3}{4}$	—
500	301-500	—	$6\frac{3}{4}$	—
2,500	0-15	$6\frac{1}{2}$	5	10″
2,500	16-30	$6\frac{1}{2}$	$5\frac{9}{16}$	10
2,500	31-60	$7\frac{1}{4}$	$6\frac{1}{8}$	$10\frac{1}{2}$
2,500	61-100	$7\frac{1}{2}$	—	11
4,400	0-20	—	—	14
6,600	0-15	—	—	17
13,200	0-10	—	—	20
22,000	0-5	—	—	23

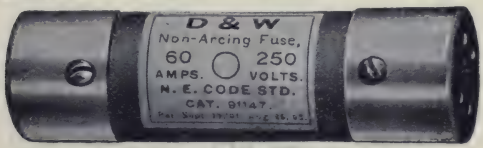
N. E. Code Std.

N. E. Code Standard

Knife Blade Contact

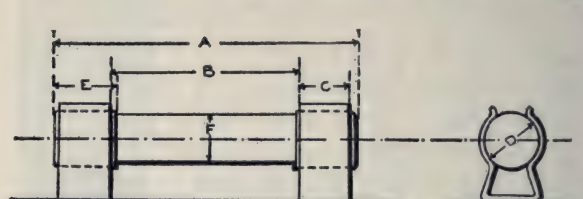
"D & W" NAT'L. ELEC. CODE STANDARD FUSES

Amperes	Volts	Length	Volts	Length
0-30	250	2″	600	5″
31-60	250	3″	600	$5\frac{1}{2}$″
61-100	250	$5\frac{7}{8}$″	600	$7\frac{7}{8}$″
101-200	250	$7\frac{1}{8}$″	600	$9\frac{5}{8}$″
201-400	250	$8\frac{5}{8}$″	600	$11\frac{5}{8}$″
401-600	250	$10\frac{3}{8}$″	600	$13\frac{3}{8}$″



N. E. Code Standard Ferrule Contact

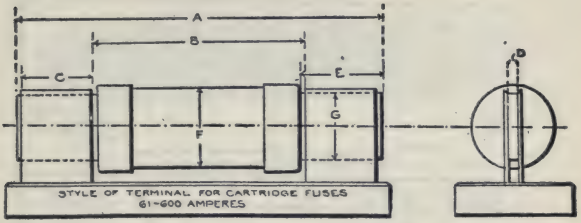
Table of Dimensions of the Standard Cartridge



Form 1. CARTRIDGE FUSE—Ferrule Contact.

Voltage.	Rated Capacity. Amperes.		A Length over Terminals. Inches.	B Distance between Contact Clips. Inches.	C Width of Contact Clips. Inches
0-250	0-30	Form 1	2	1	$\frac{1}{2}$
	31-60		3	$1\frac{1}{4}$	$\frac{5}{8}$
	61-100	Form 2	$5\frac{7}{8}$	4	$\frac{7}{8}$
	101-200		$7\frac{1}{8}$	$4\frac{1}{2}$	$1\frac{1}{4}$
	201-400		$8\frac{5}{8}$	5	$1\frac{5}{4}$
	401-600		$10\frac{5}{8}$	6	$2\frac{1}{8}$
251-600	0-30	Form 1	5	4	$\frac{1}{2}$
	31-60		$5\frac{1}{2}$	$4\frac{1}{4}$	$\frac{5}{8}$
	61-100	Form 2	$7\frac{7}{8}$	6	$\frac{7}{8}$
	101-200		$9\frac{5}{8}$	7	$1\frac{1}{4}$
	201-400		$11\frac{5}{8}$	8	$1\frac{5}{4}$

National Electrical Code
Enclosed Fuse.



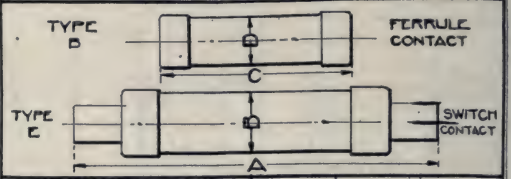
Form 2. CARTRIDGE FUSE—Knife Blade Contact.

D	E	F	G	
Dia. of Ferrules or Thickness of Terminal Blades. Inches.	Min. Length of Ferrules or of Terminal Blades Outside of Tube. Inches.	Dia. of Tube. Inches.	Width of Terminal Blades. Inches.	Rated Capacity. Amperes
$\frac{9}{16}$ $\frac{13}{16}$	$\frac{1}{2}$ $\frac{5}{8}$	$\frac{1}{2}$ $\frac{3}{4}$	Form 1	0-30 31-60
$\frac{1}{8}$ $\frac{3}{16}$ $\frac{1}{4}$ $\frac{1}{4}$	1 $1\frac{3}{8}$ $1\frac{7}{8}$ $2\frac{1}{4}$	1 $1\frac{1}{2}$ 2 $2\frac{1}{2}$	$\frac{3}{4}$ $1\frac{1}{8}$ $1\frac{5}{8}$ 2 Form 2	61-100 101-200 201-400 401-600
$\frac{13}{16}$ $1\frac{1}{16}$	$\frac{1}{2}$ $\frac{5}{8}$	$\frac{3}{4}$ 1	Form 1	0-30 31-60
$\frac{1}{8}$ $\frac{3}{16}$ $\frac{1}{4}$	1 $1\frac{3}{8}$ $1\frac{7}{8}$	$1\frac{1}{4}$ $1\frac{3}{4}$ $2\frac{1}{2}$	$\frac{3}{4}$ $1\frac{1}{8}$ $1\frac{5}{8}$ Form 2	61-100 101-200 201-400

"NOARK" FUSES.

H.W. JOHNS-MANVILLE CO.

N.E.C. STANDARD.



VOLTS	AMPS.	A	B	C	D
250	0-30			2	½
	31-60			3	¾
	61-100	5 ⅞	1		
	101-200	7 ⅛	1½		
	201-400	8 ⅝	2		
	401-600	10 ⅜	2½		
600	0-30			5	¾
	31-60			5½	1
	61-100	7 ⅞	1¼		
	101-200	9 ⅝	1¾		
	201-400	11 ⅜	2½		
"NOARK" STANDARD.					
250	601-800	11½	3		
	801-1000	12 ⅜	3½		
600	401-600	13 ⅜	3		
	601-800	14½	3½		
	801-1000	15 ⅝	4		
2500	0-30	10	1¼		
	31-60	10½	1¾		
	61-100	11	2		
4400	½-20	14	1¾		
6600	½-15	17	1¾		
13200	½-10	20	1¾		
22000	½-5	23	1¾		

"ARKLESS" INDICATING FUSES

DETROIT FUSE & MANUFACTURING CO.

NATIONAL ELECTRICAL CODE STANDARD

250 Volts

Rated Capacity. Amperes	Length over Terminals Inches	Distance C to C Contact Clips Inches	Distance between Contact Clips Inches	Width of Contact Clips Inches	Dia. of Tube Inches
0-30	2	1½	1	½	½
31-60	3	2⅜	1¾	⅝	¾
61-100	5⅞	4⅞	4	⅞	1
101-200	7⅛	5¾	4½	1¼	1½
201-400	8⅝	6¾	5	1¾	2
401-600	10⅜	8⅛	6	2⅛	2½

600 Volts

0-30	5	4½	4	½	¾
31-60	5½	4⅞	4¼	⅝	1
61-100	7⅞	6⅞	6	⅞	1¼
101-200	9⅝	8¼	7	1¼	1¾
201-400	11⅝	9¾	8	1¾	2½

"UNION" NON-ARCING ENCLOSED FUSES AND BLOCKS.

250-Volt N. E. Code Standard

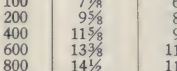
Type B, 3–60 Amp.

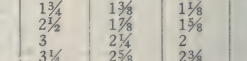
Type E, 61–1000 Amp.

Amps.	A	B	C	D	E	F	G
3– 30	2	1 1/2	1	1/2	1/2	9/16	... .
31– 60	3	2 3/8	1 3/4	3/4	5/8	13/16	.....
61– 100	5 7/8	4 7/8	3 7/8	1	1	1 3/4	1/8
101– 200	7 1/8	5 3/4	4 3/8	1 1/2	1 3/8	1 1/4	3/16
201– 400	8 3/8	6 3/4	4 7/8	2	1 7/8	1 5/8	1/4
401– 600	10 3/8	8 1/8	5 7/8	2 1/2	2 1/4	2	1/4
601– 800	11 1/2	8 7/8	6 1/4	3	2 5/8	2 3/8	3/8
801–1000	12 5/8	9 1/2	6 3/4	3 1/2	2 15/16	2 5/8	3/8

600-Volt N. E. Code Standard

Amps.	A	B	C	D	E	F	G
3– 30	5	4 1/2	4	3/4	1/2	13/16	.....
31– 60	5 1/2	4 7/8	4 1/4	1	5/8	1 1/16	.....
61– 100	7 7/8	6 7/8	5 7/8	1 1/4	1	1 3/4	1/8
101– 200	9 3/8	8 1/4	6 7/8	1 3/4	1 3/8	1 1/8	3/16
201– 400	11 5/8	9 3/4	7 7/8	2 1/2	1 7/8	1 5/8	1/4
401– 600	13 3/8	11 1/8	8 7/8	3	2 1/4	2	1/4
601– 800	14 1/2	11 7/8	9 1/2	3 1/4	2 3/8	2 3/8	3/8
801–1000	15 5/8	12 1/2	9 3/4	4	2 15/16	2 5/8	3/8

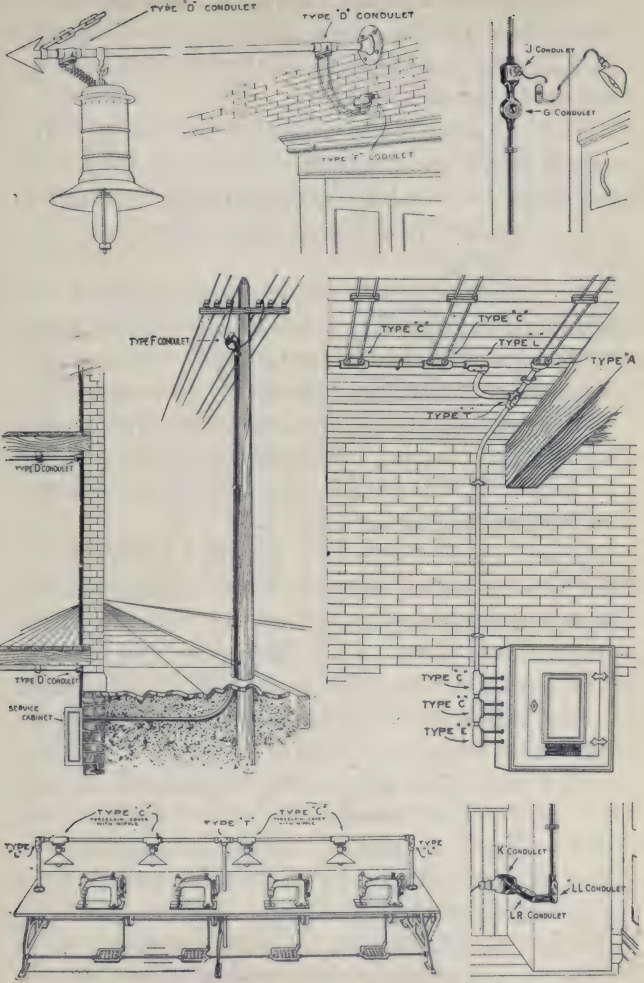




250 VOLTS.		
Cat. No.	Amp.	Description.
2003	3– 30	One wire main.
2010	"	Two wire main.
2012	"	Three wire main.
2020	"	2 wire, 2 pole, single branch.
2022	"	3 wire, 3 pole, single branch.
2025	"	2 wire, 2 pole, double branch.
2029	"	3 wire, 3 pole, double branch.
2027	"	3 wire, 2 pole, double branch.
2004	31– 60	One wire main.
2011	"	Two wire main.
2013	"	Three wire main.
2021	"	2 wire, 2 pole, single branch.
2023	"	3 wire, 3 pole, single branch.
	"	2 wire, 2 pole, double branch.
	"	3 wire, 3 pole, double branch.
	"	3 wire, 2 pole, double branch.
	61–100	Single pole, main line.

250 VOLTS.		
Cat. No.	Amp.	Description.
2014	61–100	D'ble pole, main line.
2015	61–100	Tri'le pole, main line.
2006	101–200	Sing. pole, main line.
2007	201–400	Sing. pole, main line.
2008	401–600	Sing. pole, main line.

600 VOLTS.		
4003	3– 30	One wire main.
4004	31– 60	" "
4005	61–100	" "
4006	101–200	" "
4007	201–400	" "
4008	401–600	" "



A Few of the Many Applications of "Condulets" for Inside and Outside Wiring.

Incandescent Lamps in Series Circuits should be wired with the same precaution as for series arc lighting and each lamp should be provided with an automatic cut-out.

Each lamp should be suspended from an approved hanger board by means of a rigid tube to prevent the wires from contact with nearby objects and to prevent possibility of breaking the wires from constant swinging.

No electro-magnetic device for switches and no system of multiple-series or series-multiple lighting in this class of work should be used. Under no circumstances should incandescent lamps in series circuits be attached to gas fixtures, as the high voltage necessarily employed in this class of lighting should be kept as far as possible from gas piping, which is so thoroughly grounded or likely to be.

When incandescent lamps are used for decorative purpose, as in the case of miniature colored lamps, and it is necessary to run two or more in series, permission should always be secured, in writing, from the Inspection Department having jurisdiction.

Arc Lamps should be carefully isolated from inflammable material, should be provided at all times with a glass globe surrounding the arc and securely fastened upon a closed base. No broken or cracked globes should be used, as they are designed to prevent hot bits of carbon or even an entire carbon from falling to the floor should it fall from the carbon holder. All globes for inside work should be covered with a wire netting having a mesh not exceeding one and one-quarter inches, to retain the pieces of the globe in position should the latter be

come broken from any cause. A globe thus broken should be replaced at once. When arc lamps are used in rooms containing readily inflammable material they should be provided with approved *spark arresters,* which should be made to fit so closely to the upper orifice of the globe that it will be impossible for any sparks thrown off by the carbons to escape. It is safer to use plain carbon and not copper-plated ones in such rooms, or better still, an enclosed arc lamp, one having its carbons enclosed in a practically tight glass globe which is inside the outer globe. Where hanger-boards are not used arc lamps should be hung from insulating supports other than their conductors.

All arc lamps should be provided with reliable stops to prevent carbons from falling out in case the lamps become loose, and all exposed parts should be carefully insulated from the circuit. Each lamp for constant current systems, should be provided with an approved hand switch, and also an automatic switch that will shunt the current around the carbons, so that the lamp will thus cut itself out of circuit should the carbons fail to feed properly. If the hand switch is placed anywhere except on the lamp itself it should comply in every respect with the requirements for switches on hanger-boards as described under the latter heading.

Arc Light Wiring (High Potential.) All wiring for high potential arc lighting circuits should be done with "Rubber Covered" wire. The wires should be arranged to enter and leave the building through an approved doubled contact service switch which should close the main circuit and disconnect

the wires in the building when turned "off" and be so constructed that they will be automatic in their action, not stopping between points when started and to prevent arcing between points under any circumstances, and should indicate plainly whether the current is "on" or "off." Never use snap switches for arc lighting circuits. All arc light wiring of this class should be in plain sight and never inclosed, except when required, and should be supported on porcelain or glass insulators which separate the wires at least one inch from the surface wired over. The wires should be kept rigidly at least eight inches apart, except of course within the lamp, hanger board or cut-out box or switch. On side walls, the wiring should be protected from mechanical injury by a substantial boxing, retaining an air space of one inch around the conductors, closed at the top (the wires passing through bushed holes), and extending not less than seven feet from the floor. When crossing floor timbers in cellars or in rooms, where they might be exposed to injury, wires should be attached by their insulating supports to the under side of a wooden strip not less than one-half an inch in thickness.

Arc Lamps on Low Potential Circuits should have a cut-out for each lamp or series of lamps. The branch conductors for such lamps should have a carrying capacity about 50 per cent. in excess of the normal current required by the lamp or lamps to provide for the extra current required when the lamps are started or should a carbon become stuck without over-fusing the wires. If any resistance coils are necessary for adjustment or regulation.

they should be enclosed in non-combustible material and be treated as sources of heat; it is preferable that such resistance coils be placed within the metal framework of the lamp itself. Incandescent lamps should never be used for resistance devices. These lamps should be provided with globes and spark arresters, as in the case of arc lamps on high-potential series circuits, except when the enclosed arc lamps are used.

Economy Coils or compensator coils for arc lamps should be mounted on glass or porcelain, allowing an air space of at least one inch between frame and support, and in general to be treated like sources of heat.

Hanger Boards should be so constructed that all wires and current-carrying devices thereon will be exposed to view and thoroughly insulated on non-combustible, non-absorptive insulating substance, such as porcelain.

All switches attached to the hanger-board should be so constructed that they will be automatic in their action, cutting off both poles to the lamp, not stopping between points when started, and preventing an arc between points under all circumstances.

Electric Heaters should always be treated as sources of heat and kept away from inflammable materials. Each heater should have a cut-out and *indicating* switch and all attachments from the feed wires to the heater should be kept in plain sight, easily accessible and protected from interference. Each heater should have a name plate giving the maker's name, and the normal capacity in volts and amperes.

Car House Wiring. All trolley wires in car houses should be securely supported on insulating hangers. The trolley hangers should be placed close enough together to prevent the trolley wire, should it break from any cause, from coming in contact with the floor or rails within the building, or even in contact with the ironwork on the trucks or wheels of the car, as it hangs down. A broken trolley wire in this way would produce dangerous arcing and probably start a fire.

All the wires in the car house should be controlled by a cut-out switch, located on a pole at least one hundred feet from the building, so that in case of fire or for other reasons all wires could be controlled from that point. The current should always be cut out of the car house when the same is not in use or the road not in operation. All lamps and stationary motors used in car houses should be installed in such a way that one main switch can control the whole of each installation independently of the main feeder switch. No portable incandescent lamps or twin wire should be used, except in the car pits, where they may be used when connections are made by two approved rubber-covered flexible wires, properly protected against mechanical injury, and all such pit wiring be controlled by a separate switch for each pit placed outside of the pit. All wiring for lights or motors within the car house should be with approved rubber-covered wire and supported on single porcelain or glass insulators which separate the wires from surface wired over by one inch. No system of feeder distribution should center in the car house.

All rails within the building should be bonded at

each joint with annealed copper wire, not smaller than No. oo B. & S. gauge.

When cars are run in the house they should not be left with their trolleys in contact with the trolley wire, as frequent fires have been caused by the motorman or conductor forgetting to turn off the car heater current or other car wiring, and during the course of the night, or other times, "burn-outs" have occurred, followed by fire and, as once happened in the course of the writer's experience, the total loss of a large car house and a number of valuable cars and other stock. Current from trolley systems, having a grounded return wire, should never be used for any purpose in or on buildings other than car houses or their power stations.

Approved Apparatus and Supplies. Every article or fitting intended for use in electrical wiring or construction or in connection therewith should, before being manufactured or placed upon the market, be submitted to the Underwriters' Laboratories, 382 Ohio street, Chicago, for examination and report. When such article or device is approved and found safe and suitable for the use intended, it is placed on the List of Electrical Fittings issued semi-annually by the National Board of Fire Underwriters, for use in accordance with the rules and requirements of the National Electrical Code as given in the foregoing pages of this book.

Any new article, therefore, or modification of an old article, intended to be placed in general electrical use, should first be sent for examination and test to the laboratory of the Electrical Bureau of the National Board of Fire Underwriters, 382 Ohio street, Chicago, Ill.

When buying electrical supplies of any description make sure that they have been approved, or that their use will be permitted. If there is any question about it, make your supply dealer, or the manufacturer give you a guarantee that they will be approved by the Fire Underwriters' Inspector if installed in accordance with the rules and requirements of the National Board of Underwriters.

Electrical Inspection. The principal points regarding the safe installation of dynamos, motors, outside and inside wiring, as required by the insurance underwriters, have been briefly set forth in this little book, which has been compiled simply for reference and not as a teacher—a book designed to settle most of the doubtful questions which might arise in the mind of the engineer or contractor as to just what will be considered safe by insurance inspectors. There will probably arise questions which cannot be settled by reference to the suggestions herein contained, and, therefore, a great deal has to be left to the judgment of the constructing engineer and inspector. In every such case the Inspection Department having jurisdiction should be consulted with perfect assurance that nothing unreasonable will ever be demanded in the way of special construction.

Every piece of wiring or electrical construction work, whether open or concealed, should be inspected, and *notice,* therefore, *should always be sent by the contractor or engineer to the board having jurisdiction immediately upon completion of any work.* Negligence in this matter has frequently caused floors to be torn up when doubtful work has been suspected, and at the cost of the parties who installed the wiring.

ALTERNATING CURRENT WIRING.

Prepared especially for "Standard Wiring"
by E. W. ALLEN.

Alternating current flowing through a line encounters a drop in voltage, due not only to the ohmic resistance, but also to certain other phenomena caused by the rapid changes in the value and direction of the current. The phenomena referred to are the Self Induction, the Mutual Induction and the Skin, or Surface Effect of the conductors.

Self Induction A conductor or wire through which a current of electricity is flowing is surrounded by a magnetic field of strength proportional to the current flowing. The periodic reversals of an alternating current are accompanied by similar changes in this magnetic field which generate in the conductor a counter E. M. F. The value of this counter E. M. F. of Self Induction is dependent upon the length and size of the conductor, the amount of current and the frequency of the alternations.

Mutual Induction. Mutual Induction is the effect of one alternating current circuit upon another. It is caused by the magnetic field surrounding a conductor cutting adjacent conductors and inducing in them opposing E. M. F.'s.

Skin Effect. Alternating current is not uniformly distributed throughout the cross section of a conductor, but is apparently denser at or near its surface. If the frequency is high and the conductor of large diameter, the central portion carries little,

if any, current, and the resistance of large conductors is, therefore, greater for alternating than for direct current. The skin effect can be partially overcome by using a number of multiple conductors having a total cross section approximately the same as that of a single large conductor if direct current were used. Cables for connecting the collector rings of large synchronous converters to the secondary or low tension side of their step-down transformers are for this reason often built with a rope core.

At frequencies of 60 cycles, or less, and with conductors having a cross section not exceeding that of 0000 B. & S., the surface, or skin effect, may, for all practical purposes, be neglected.

The skin effect of large conductors may be obtained from the following table (reprinted from Alternating Current Wiring, by W. L. R. Emmet):

TABLE I

Product of Cir. Mils. × Cycles per sec.	Factor	Product of Cir. Mils. × Cycles per sec.	Factor
10,000,000	1.00	70,000 000	1.13
20,000,000	1.01	80,000.000	1.17
30,000,000	1.03	90,000,000	1.20
40,000 000	1.05	100,000,000	1.25
50,000,000	1 08	125 000,000	1.34
60,000,000	1.10	150,000,000	1.43

The factors given in this table multiplied by the resistance to direct currents will give the resistance to alternating currents for copper conductors of circular cross section.

Resistance Reactance & Impedance. The volts lost in an alternating current circuit may be resolved into two components representing respectively the loss due to resistance and the loss due to the reactance or counter E. M. F.'s generated in

the circuit. The loss due to reactance is displaced in phase 90° from the loss due to resistance and they may, therefore, be represented as forming the two legs of a right triangle. The hypothenuse of the triangle thus formed will represent the combined effect of all the factors which retard the flow on an alternating current and is called the impedance of the circuit and is measured in ohms. The reactance and impedance, like the self induction, depend upon the length of the circuit, the frequency, the size of conductor, and the distance between the two wires forming the circuit. If the wires are brought close together the reactance is reduced and practically disappears if the wires are twisted together to form a *2* conductor cable. The impedance would then become equal to the resistance. (See Fig. 1, p. 131.)

Apparent Energy & Power Factor. The current flowing in an A. C. circuit as measured by an ammeter can be resolved into two components, representing respectively the energy current and the wattless or idle current due to the counter E. M. F. of induction mentioned above. These components, like the voltages that produce them, are also displaced in phase 90° and form the two legs of a right triangle, the hypothenuse of which is the current measured by the ammeter. (See Fig. 2, p. 131.)

It is evident from the figure that the current as measured by an ammeter exceeds the true energy current and lags in phase by an amount represented by the angle Φ. The cosine of this angle, or the ratio True Energy, divided by the apparent energy, is called the *power factor* of the system and is ex-

pressed in per cent. of the apparent energy. For example, a single-phase circuit delivering 100 kw. at 250 volts and .8 P. F. would have a current as measured by the ammeter of $\frac{100000}{250 \times .8} = 500$ amperes, although the energy or useful current would be only 400 amperes. With these values we may construct a right triangle having as its hypothenuse the apparent current 500 amperes, the energy current 400 amperes as one of its sides, and a wattless component of 300 amperes (see Fig. 3, p. 131), as the other side. The wattless component is found by taking the square root of the difference between the squares of the hypothenuse and the known side. If the wattless component and the energy component were known, the apparent energy or the hypothenuse of the triangle could be found by taking the square root of the sum of their squares. A better understanding of the wattless component, or idle current, may be had if we remember that with a strictly non-inductive load the wave of current coincides with the wave of E. M. F., both reversing at the same instant. With an inductive load, however, the wave of current lags behind the wave of E. M. F. and its reversals in direction do not occur until after the reversal of the E. M. F. wave. It is evident that during the interval between these two reversals the current will oppose the voltage and consequently the momentary product of these two waves at that time will produce no effect upon a wattmeter coil which only reads the true energy.

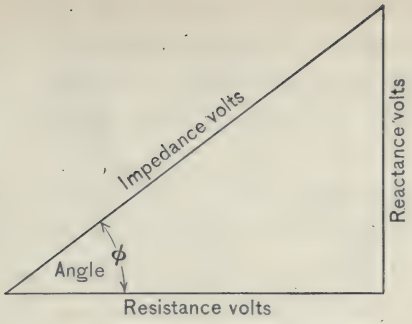


Fig. 1

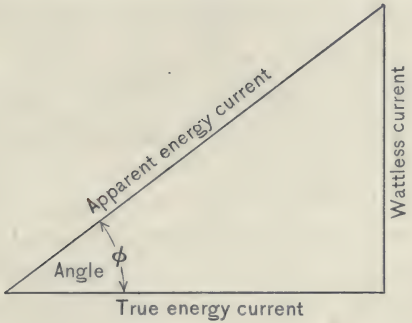


Fig. 2

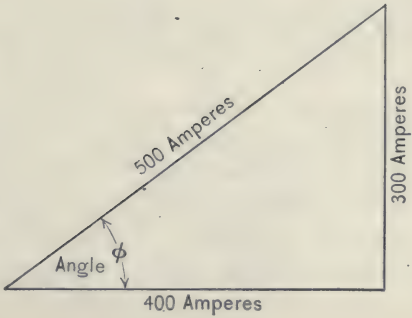


Fig. 3

The product of the independent values of current and voltage, or the volt amperes, as read on the ammeter and voltmeter will, therefore, always exceed the true energy in a line carrying an inductive load.

The heating effect of this wattless or idle current is equivalent to the heating effect of the same *amount of energy current, and the important fact to remember about an alternating current load is that the current corresponding to the apparent load (the hypothenuse of the triangle in Fig. 3) determines the heating of the wire.*

The power factor of an A. C. system, or the *true energy,* divided by the apparent energy, depends upon the character of the load. If made up of incandescent lamps, the power factor will be practically unity, and the apparent energy as determined by the volt and ammeter readings may then be taken as the true energy. If, on the contrary, the load is made up of induction motors, the power factor will always be less than unity by an amount depending upon the extent to which the motors are loaded.

In commercial circuits a load made up exclusively of induction motors will have a power factor of about .7. A mixed load of incandescent lamps and induction motors will have a power factor of from .8 to .85.

The power factor of several representative induction motors is given in the following table:

TABLE 2

Horse Power	Speed	Efficiency			Power Factor		
	Full Load Speed	1	¾	½	1	¾	½
2	1700	83	82	82	83	76	63
5	1700	86	86	85	89	84	73
10	1700	89	89	88	90	86	75
35	1150	90	90	89	90	87	81

It is evident from the preceding pages that the calculation of the conductors or wires for alternating current circuits must take into consideration both the impedance of the circuit and the power factor of the load.

Formulæ and tables for calculating the approximate size of conductors, the volts lost in the line, and the current per conductor in any system of alternating current distribution are given below. The formulæ have been widely used for a number of years, and in presenting them here no claim is made for originality. The tables which generally accompanied them have been revised and extended especially for this book.

The size of copper conductors for any system of electrical distribution may be determined from the following formula:

$$\text{Cir. Mils} = \frac{D \times W \times K}{P \times E^2}$$

W = Total watts delivered.

D = Distance of transmission (one way) in feet.

P = Loss in line in per cent. of power de-

livered, that is of *W*. It must be used in the formula as a whole number and not as a decimal—thus 5% energy loss should appear in the denominator as 5 and not .05.

E = Voltage between main conductors at receiving or consumers' end of circuit.

K = Refer to table on page 135.

B = Refer to table on page 136.

T = Refer to table on page 135.

The volts lost in the line may be determined as follows:

$$\text{Volts lost in line} = \frac{P \times E}{100} \times B$$

$$\text{Current in line} = \frac{W}{E \times T}$$

APPLICATION OF FORMULAE.

The formula for determining the area of the conductor will be recognized as the general formula for direct current. It may be applied to any system of alternating current distribution by selecting the proper value for the constant "K." The value of "K" for direct current is 2160, and is obtained by multiplying $10.8 \times 2 \times 100$.

10.8 is the resistance of a copper conductor 1 mil in diameter and 1 foot in length.

Multiplying by *2* enables us to express the distance *D* in feet one way. Multiplying by 100 enables us to use *P* in the formula as a whole number rather than as a decimal.

VALUES OF "K"

System	Power Factor				
	1.00	.98	.90	.80	.70
Single Phase	2160	2240	2660	3380	4400
Two " 4 Wire	1080	1120	1330	1690	2200
Three " 3 "	1080	1120	1330	1690	2200

VALUES OF "T"

System	Power Factor				
	100	.98	.90	.80	.70
Single Phase	100	.98	.90	.80	.70
Two " 4 Wire	2.00	1 96	1.80	1.60	1.40
Three " 3 "	1 73	1 70	1.55	1.38	1.21

When applied to alternating current the value of "K" for any particular power factor is found by dividing 2160 by the square of that power factor for single phase and twice the square of the power factor for 3-wire 3-phase. and 4-wire 2-phase.

The value of "B" depends upon the size of wire, the distance between conductors, the frequency and power factor. The values of "B" given in the tables on pages 136 and 137, are sufficiently accurate for all practical purposes and may be used for distances of 20 miles or less and for voltages of 25000 or less. The capacity effect, or charging current of very long high voltage lines, makes this method of determining the volts lost somewhat inaccurate beyond the limits specified above.

In using the formula and constants it should be particularly observed that "P" stands for the per cent. loss in the line of the power delivered and is not the per cent loss of the power at the generator.

Single-Phase System. The watts in a single-phase system of unity power factor (non-inductive load) are equal to the product of the volts $\times$ amperes. If the power factor is less than unity, the watts will be equal to the product of the volts $\times$ amperes $\times$ per cent. power factor, and will, therefore, always be less than the product volts $\times$ amperes.

Two-Phase System. The watts in a 2-phase 4-wire system of unity power factor are equal to the volts $\times$ amperes in phase No. 1, plus the volts $\times$ amperes in phase No. 2. If the power factor is less than unity the volt amperes should be multi-

VALUES OF "B" FOR 60 CYCLES

Size of Wire	Resistance per 1000 feet.	Wt. per 1000 feet.	.98 Power Factor — Spacing of Conductors					.90 Power Factor — Spacing of Conductors					.80 Power Factor — Spacing of Conductors					.70 Power Factor — Spacing of Conductors					Area in Cir. Mils.
			1″	3″	6″	12″	24″	1″	3″	6″	12″	24″	1″	3″	6″	12″	24″	1″	3″	6″	12″	24″	
500000	.0202	1553.	1.21	1.45	1.61	1.77	1.92	1.32	1.80	2.11	2.44	2.75	1.27	1.89	2.25	2.64	3.03	1.14	1.72	2.12	2.53	2.92	500000
300000	.0345	932.	1.15	1.29	1.38	1.48	1.57	1.19	1.47	1.66	1.84	2.02	1.11	1.46	1.68	1.90	2.12	1.00	1.33	1.56	1.78	2.01	300000
0000	.0499	641	1.12	1.22	1.28	1.34	1.41	1.13	1.33	1.45	1.58	1.63	1.03	1.27	1.43	1.58	1.75	1.00	1.14	1.29	1.45	1.69	212000
000	.0628	509	1.09	1.18	1.22	1.28	1.29	1.08	1.23	1.33	1.44	1.53	1.00	1.16	1.28	1.41	1.53	1.00	1.02	1.15	1.28	1.50	168000
00	.0794	403	1.07	1.14	1.18	1.21	1.25	1.03	1.16	1.24	1.32	1.40	1.00	1.07	1.17	1.27	1.36	1.00	1.00	1.03	1.13	1.21	133000
0	.0997	320	1.05	1.10	1.14	1.17	1.20	1.00	1.09	1.16	1.22	1.28	1.00	1.00	1.07	1.15	1.22	1.00	1.00	1.00	1.01	1.09	106000
1	.126	253	1.04	1.08	1.10	1.13	1.15	1.00	1.05	1.09	1.14	1.19	1.00	1.00	1.00	1.05	1.11	1.00	1.00	1.00	1.00	1.00	83500
2	.159	202	1.02	1.05	1.08	1.10	1.12	1.00	1.00	1.04	1.08	1.12	1.00	1.00	1.00	1.00	1.02	1.00	1.00	1.00	1.00	1.00	66600
3	.202	159	1.02	1.04	1.06	1.07	1.09	1.00	1.00	1.00	1.03	1.06	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	52400
4	.254	126																					41600
5	.319	100	1.00	1.02	1.03	1.04	1.07	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	33100
6	.403	79.5																					26200
7	.510	62.8	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	20600
8	.635	50.4																					16600
9	.813	39.4	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	13000
10	1.01	31.5																					10400

VALUES OF "B" FOR 25 CYCLES

Size of Wire	Resistance per 1000 feet.	Wt. per 1000 feet.	.98 Power Factor					.90 Power Factor					.80 Power Factor					.70 Power Factor					Area in Cir. Mils.
			Spacing of Conductors					Spacing of Conductors					Spacing of Conductors					Spacing of Conductors					
			1″	3″	6″	12″	24″	1″	3″	6″	12″	24″	1″	3″	6″	12″	24″	1″	3″	6″	12″	24″	
500000	.0202	1553.	1.01	1.17	1.23	1.29	1.36	1.02	1.22	1.35	1.43	1.61	1.00	1.15	1.30	1.47	1.62	1.00	1.00	1.16	1.33	1.49	500000
300000	.0345	932.	1.04	1.10	1.13	1.18	1.21	1.00	1.08	1.16	1.25	1.31	1.00	1.00	1.09	1.16	1.25	1.00	1.00	1.00	1.02	1.12	300000
0000	.0499	641	1.03	1.07	1.09	1.11	1.14	1.00	1.02	1.07	1.13	1.15	1.00	1.00	1.00	1.03	1.10	1.00	1.00	1.00	1.00	1.00	212000
000	.0628	509	1.00	1.05	1.06	1.09	1.10	1.00	1.00	1.02	1.07	1.11	1.00	1.00	1.00	1.00	1.01	1.00	1.00	1.00	1.00	1.00	198000
00	.0794	403	1.00	1.03	1.05	1.06	1.08	1.00	1.00	1.00	1.02	1.05	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	133000
0	.0997	320	1.00	1.01	1.02	1.03	1.04	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	106000
1	.126	253																					83500
2	.159	202	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	66600
3	.202	159																					52400
4	.254	126																					41600
5	.319	200	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	33100
6	.403	79 .5																					26200
7	.510	62 .8																					20600
8	.635	50 .4	1.00	1.00	1.00	1.00	1.00	2.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	16600
9	.813	36 .4																					13000
10	1.01	31 .5																					10400

plied by the per cent. power factor, as shown in the preceding case. The current in each phase is equal to ½ the current in a single-phase system of the same voltage and delivering the same load. The wires for a 2-phase system will therefore be ½ as large as the wires needed for a single-phase line of the same voltage and load, but as 4 wires are needed, the total weight of copper required for this system of transmission is the same as that required for single phase.

Three-Phase System. The watts in a 3-phase 3-wire system of unity power factor are equal to the product volts $\times$ amperes $\times \sqrt{3} = 1.73$. If the power factor is less than unity the product thus obtained should be multiplied by the per cent. power factor as explained for other systems. It is evident from the above that the current in a 3-phase system equals the $\frac{\text{Watts}}{\text{Volts} \times 1.73 \times \text{Power factor}}$. The product 1.73 $\times$ power factor will be found the same as the value of "T" in table (1), page (135). Each wire of a 3-phase system will be equal in size to one of the wires of a single-phase system of the same voltage carrying ½ the load carried by the 3-phase system. The total weight of copper for a 3-phase system is therefore only 75% of that required for either a single-phase or a 2-phase system delivering the same load.

Examples:

(1) Given—

D = 1000 (distance [one way] in feet).
E = 440 = volts at end of line.
W = 25000 watts (25 kilowatts).
P = 5% energy loss (to be used in formula as 5. and not as .05).
K = 3380 (refer to table on page 135).
B = 1.05 (refer to table on page 136).
T = .80 (refer to table on page 135).
Transmission single phase. Frequency = 60 cycles.
Spacing of conductors 12".
Power factor = 80.

Determine—

1st—The size of wire in circular mils.
2nd—The volts lost in the line.
3rd—The current in the line.

$$\text{Cir. mils} = \frac{D \times W \times K}{P \times E^2} = \frac{1000 \times 25000 \times 3380}{5 \times 440 \times 440}$$

$$= \frac{10562500}{121} = 87289 \text{ cir. mils use No. 1 B. \& S. wire.}$$

$$\text{Volts lost in line} = \frac{P \times E \times B}{100} = \frac{5 \times 440 \times 1.05}{100}$$

$$= 23.1 \text{ volts.}$$

$$\text{Current in line} = \frac{W}{E \times T} = \frac{25000}{440 \times .80} = 71. \text{ Amps.}$$

Example (2) Find—

The size of wire, the volts lost in line and the current in each line if a 3-phase system had been used in the previous example, other values remaining constant.

$$\text{Cir. mils} = \frac{D \times W \times K}{P \times E^2} = \frac{1000 \times 2500 \times 1690}{5 \times 440 \times 440}$$

$$= \frac{528125}{121} = 43644 \text{ cir. mils, use No. 4 B. \& S.}$$

NOTE.—The size of each conductor is only one-half that needed for single-phase transmission as obtained from the preceding example. Three conductors are needed, however, and the weight of copper will be 75% of that required for single phase.

$$\text{Volts lost} = \frac{P \times E \times B}{100} = \frac{5 \times 440 \times 1.05}{100} = 23.10$$

$$\text{Current in each line} = \frac{W}{E \times T} = \frac{25000}{440 \times 1.38}$$

$$= 41.2 \text{ Amps.}$$

Example (3) Given—

D = 500 (distance [one way] in feet).
E = 220 (volts at end of line).
W = 10000 (10 kilowatts).
K = 2240 (refer to table on page 135).
B = 1.06 (refer to table on page 136).
T = .98 (refer to table on page 135).
P = 10.

Transmission single phase. Frequency 60 cycles.

Power factor .98 (incandescent lamps).

Spacing of conductors 6″.

Find 1st the size of wire in cir. mils.

2nd the volts lost in the line.

3rd the current in the line.

$$\text{Size of wire in Cir. mils} = \frac{D \times W \times K}{P \times E^2}$$

$$= \frac{500 \times 10000 \times 2240}{10 \times 220 \times 220} = \frac{560000}{11}$$

= 50900 Cir. mils, use No. 3 B. & S. wire.

$$\text{Volts lost in line} = \frac{P \times E \times B}{100} = \frac{10 \times 220 \times 1.06}{100}$$

= 23.3 volts = 10.6% of volts delivered.

$$\text{Current in the line} = \frac{W}{E \times T} = \frac{10000}{220 \times .98}$$

= 46.5 amps.

It will be observed from the above that the volts lost in per cent. of volts delivered are approximately the same as the watts lost in per cent. of the watts delivered. This is due to the high power factor of the load, the relative small diameter of the wire and the small distances between wires.

Example (4) Given—

D = 400 = (distance one way in feet).

E = 250 volts.

W = 150000 watts (150 kilowatts).

K = 2660 (refer to table on page 135).

P = 5% energy loss.

Transmission, single phase. Frequency, 60 cycles. Power factor, .90. Spacing of conductors, 12".

Find—First the size of wire in cir. mils.

Second the volts lost in the line.

$$\text{Size of wire in Cir. mils} = \frac{D \times W \times K}{P \times E^2}$$

$$= \frac{400 \times 150000 \times 2660}{5 \times 250 \times 250}$$

= 510720 Cir. mils. Use 500,000 Cir. mil cable.

$$\text{Volts lost in line} = \frac{P \times E \times B}{100} = \frac{5 \times 250 \times 2.64}{100}$$

= 33. volts, or 13.2% of volts delivered.

It will be noted that the per cent. volts lost is more than double the per cent. energy lost. This is due to the high reactance of the 500000 Cir. Cable (refer to table on page 137) when carrying alternating current, contrasted with its resistance. It shows very clearly that with alternating current better regulation can be secured if two or more relatively small conductors in multiple are used in preference to a large conductor. The sum of the areas of the smaller conductors should, of course, be equal to the area of the large conductor.

Example (5)—

A 30 h.p., 220 volt, 3-phase, 60-cycle induction motor is located 500 ft. from a bank of step-down transformers. Find the size of wire that should

be run from the transformers to the motor, allowing 5% loss in energy.

Assume that the full load efficiency and power factor of the motor are respectively .88 and .90, and that the wires will be spaced 12" between centers

1 h.p. = 746 watts, therefore 30 h.p. = 30×746 = 22380 watts. $22380 \div 88$ eff. = 25430 watts.

$$\text{Cir. mils} = \frac{D \times W \times K}{P \times E^2} = \frac{1000 \times 25430 \times 1330}{5 \times 220 \times 220}$$

= 139750 Cir. mils. Use No. 00 B. & S. for each of the wires.

The volts loss would be $\frac{P \times E \times B}{100}$

$$= \frac{5 \times 220 \times 1.32}{100} = 14.52 \text{ V.}$$

$$\text{The current in each line} = \frac{W}{E \times T} = \frac{25430}{220 \times 1.55}$$

= 74.5 Amps.

No allowance has been made for sag in the line, which is sometimes assumed as 5%.

It is often necessary to find the voltage at the receiving end of an alternating current feeder where the size of wire, the length of the feeder, and the volts at the generator, current, etc., are known. This value can be found from the following formula:

$$E = \left(1 - \frac{I^2R}{W\,gen - I^2R} \times B\right) E\,gen.$$

E = Volts at receiving end of feeder.
E gen = Volts at generator.
W gen = Watts at generator.

$$I = \text{Current in line} = \frac{W\,gen}{E\,gen \times T}$$ (See table page 135 for value of "T.")

B = See tables on pages 136, 137.

Example (6) Given—

Size of wire = 106000 Cir. mils = No. 0.
Length of line (one way) = 500 ft.
R = .099 ohms per 1000 ft.
E gen = 240.
W gen = 40000.
Power factor = .8.
Spacing of wires 12".
System—Three phase.
Frequency—60 cycles (7200 alternations per second).
B = 1.15 (from table on page 136).
T = 1.38 = (1.73 × .8 from table on page 135).
R = .099 ohms.
Find—I (the current in the line).
E (the volts at the receiving end of the line).

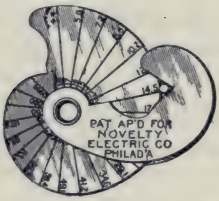
$$I = \frac{W\,gen}{E\,gen \times T} = \frac{40000}{240 \times 138} = 127.7 \text{ amps.}$$

$$E = \left(1 - \frac{I^2R}{W\,gen - I^2R} \times B\right) E\,gen$$

$$= \left(1 - \frac{127.7 \times 127.7 \times .099}{40000 - 127.7 \times 127.7 \times .099} \times 1.15\right) 240$$

$$= \left(1 - \frac{1614}{40000 - 1614} \times 1.15\right) 240$$

$$= \left(1 - \frac{1856}{38386}\right) 240 = .95 \times 240 = 228 \text{ volts.}$$



A convenient type of pocket wire gauge, one-half actual size, for measuring wire from No. 18 to No. 000 B. & S. gauge. On the front is given the safe carrying capacity of copper wires in amperes, and on the reverse side the approximate decimal equivalent of the various sizes of wires.

MISCELLANEOUS.

DEFINITIONS OF ELECTRICAL UNITS.

All electrical units are derived from the following mechanical units:

The Centimeter is the unit of length, and equals .3937 inch, or .00000000l of a quadrant of the earth.

The Gram is the unit of mass, and is equal to 15.432 grains, the mass of a cubic centimeter of water at 4° C.

The Second is the unit of time and is the time of one swing of a pendulum, swinging 86464.09 times per day, or the 1/86400th part of a mean solar day.

The Volt is the unit of electro-motive force [E].

Electromotive force, which is the force that moves electricity, is usually written E. M. F. (in formulæ E) and various writers use it to express potential, difference of potential, electric pressure and electric force.

One volt will force an ampere of current through one ohm of resistance. Its value is purely arbitrary, but fixed.

The Ohm is the unit of resistance [R] and it is equal to the resistance of a column of pure mercury 1 square millimeter in section and 106.3 centimeters long at the temperature of melting ice.

One ohm is that resistance through which one ampere of current will flow at a pressure of one volt of E. M. F.

The Megohm = 1,000,000 ohms.

The Ampere is the unit of current strength [C]. Its value may be defined as that quantity of elec-

tricity which flows through one ohm of resistance when impelled by one volt of E. M. F.

One ampere of current flowing through a batl will deposit 0.017253 grain of silver or 0.005085 grain of copper per second.

The Coulomb is the unit of quantity [Q], and is the quantity of electricity passing per second, when the current is one ampere.

The Farad is the unit of capacity [K], and is that capacity that will contain one coulomb at a potential of one volt.

A condenser of one farad capacity, if charged to two volts, will contain two coulombs; if to 100 volts, 100 coulombs, etc.

The Microfarad [mfd] = one millionth of a farad.

The Joule is the unit of work [W]. It is the work done or heat generated, by a watt in a second. It is equal to .7373 foot-pound.

The Watt is the unit of electrical power [P], and is the energy contained in a current of one ampere with an electromotive force of one volt. 746 watts = one horse-power. A current of 10 amperes and 74.6 volts will do the work of the one horse-power.

A Horse-Power in a steam engine or other prime mover is 550 lbs. raised one foot per second, or 33,000 lbs., one foot per minute.

The Kilowatt [kw] equals to 1,000 watts.

The E. M. F. is distributed according to the resistance of the various parts of the circuit, except where there is counter E. M. F.

Counter E. M. F. is like back pressure in hydraulics. Thus, to find the available E. M. F., or

the resulting current against a resistance where there is a counter E. M. F., the counter E. M. F. must be deducted. For example: Suppose a storage battery with a resistance of .02 ohm and a C. E. M. F. of 15 volts, and you wish to charge it with a dynamo which gives an E. M. F. of 20 volts at the battery binding posts. There are 20 — 15 = 5 volts working through a resistance of .02 of an ohm with consequently a current of 250 amperes. The impressed voltage is, however, 20 volts, and not 5 volts, and the power is 20 × 250 = 5000 watts, and not 5 × 250 = 1250 watts, as might perhaps be supposed. It is obvious that the C. E. M. F. has acted as a true resistance. In the above case 5 × 250 = 1250 watts were wasted in overcoming the resistance of the storage battery and the remaining 3750 watts were stored up in the chemical changes which they brought about in the active material of the storage battery.

Mils = Thousandths of an inch.

d^2 = circular mils.

The Circular Mil is now generally used as the unit of area when considering the cross-section of electric conductors, the resistance being inversely, and weight of copper directly, proportional to the circular mils.

General Formulae (Ohms Laws).

C. = current in amperes.

E. = electromotive force in volts.

R. = resistance in ohms.

W. = energy in watts.

$$C. = \frac{E.}{R.} \qquad E. = C.R. \qquad R. = \frac{E.}{C.}$$

$$C.\ E. = W. \qquad W. = \frac{E^2}{R} \qquad C^2\ R. = W.$$

$$\frac{W.}{746} = H.P. \qquad W. = 746 \times H.P.$$

Formulæ giving the volts or amperes necessary for a given horse-power on circuits of constant current, and constant potential, respectively:

$$E. = \frac{746 \times H.P.}{C. \times K.}$$

$$C. = \frac{746 \times H.P.}{E. \times K.}$$

E. = potential of circuit.
C. = amperes.
K. = efficiency of machine.
H.P. = horse-power.

General Formulae for Direct Current Light and Power Wiring. When possible use the tables on pages 51 and 67, for convenience.

c.m. = circular mils
d. = length of wire, in feet, on one side of circuit.
n. = number of lamps in multiple.
c. = current in amperes per lamp.
v. = volts lost in lines.
r. = resistance per foot of wire to be used.
10.8 ohms = resistance of one foot of commercial copper wire having a diameter of one mil and a temperature of 75° Fahrenheit.

It is an easy matter to find any of the above values by the following formulæ for direct current:

$$\text{c.m.} = \frac{10.8 \times 2\text{d.} \times \text{n.} \times \text{c.}}{\text{v.}}$$

$$\text{v.} = \frac{10.8 \times 2\text{d.} \times \text{n.} \times \text{c}}{\text{c.m.}} \qquad \text{c.} = \frac{\text{c.m.} \times \text{v.}}{10.8 \times 2\text{d.} \times \text{n.}}$$

$$\text{n.} = \frac{\text{c.m.} \times \text{v.}}{10.8 \times 2\text{d.} \times \text{c.}} \qquad 2\text{d.} = \frac{\text{c.m.} \times \text{v.}}{10.8 \times \text{c.} \times \text{n.}}$$

$$\text{r.} = \frac{\text{v.}}{\text{n.} \times \text{c.} \times 2\text{d.}}$$

$$\text{v.} = \text{n.} \times \text{c.} \times 2\text{d.} \times \text{r.} \qquad \text{c.} = \frac{\text{v.}}{2\text{d.} \times \text{n} \times \text{r.}}$$

$$\text{n.} = \frac{\text{v.}}{\text{c.} \times 2\text{d.} \times \text{r.}} \qquad 2\text{d.} = \frac{\text{v.}}{\text{n.} \times \text{c.} \times \text{r.}}$$

To find the efficiency of incandescent lamps when:

C. = current in amperes.

E. = electromotive force in volts.

$$\text{R.} = \frac{\text{E}}{\text{C}} = \text{resistance of lamp, hot.}$$

C.P. = candle-power of lamp.

W. c.p. = watts candle-power (a measure of efficiency of lamp).

One electrical H.P. = 746 watts.

$$\text{Watts per C.P.} = \frac{\text{C.} \times \text{E.}}{\text{C. P.}}$$

$$\text{Number candles per electric H.P.} = \frac{746}{\text{W.c.p.}}$$

As the efficiency of conversion of good dynamos is 90 per cent., the calculations of candles per electrical H.P. must be multiplied by this factor to give the number of candles per mechanical horse-power.

The weight and resistance per mile of round wire, where d. is the diameter in mils, are:

	Weight.	Resistance at 75°
For copper wire	$\frac{d^2}{62.5}$ lbs.	$\frac{380060}{d^2}$ ohms.
For iron wire	$\frac{d^2}{72}$ lbs.	$\frac{56970}{d^2}$ ohms.

To ascertain the sectional area:

Diameter = d.

Sectional area in circular mils = d^2.

Copper wire is 1.14 times the weight of an iron wire of the same size.

A copper wire 334 circular mils in cross-section and 1000 feet in length weighs one pound.

The percentage of conductivity of any wire is found by multiplying the resistance of a pure wire of the same length and weight at the same temperature by 100, and dividing the product by the resistance of the wire as measured.

MEMORANDUM OF IRON, STEEL AND COPPER WIRE.

Gauge.	Diameter in .001 inch.			Pounds in One Mile.				Feet in One Pound.				Resistance in Ohms Per Mile.			
	Galvanized Iron B. W. G.	Copper B. & S.	Copper Old B. W. G.	Galvanized Iron B. W. G.	Galvanized Steel.	Copper B. & S.	Copper Old B. W. G.	Galvanized Iron B. W. G.	Galvanized Steel.	Copper B. & S.	Copper Old B. W. G.	Galvanized Iron B. W. G.	Galvanized Steel B. W. G.	Copper, B. & S., 60° Fah.	Copper, Old B. W. G., 60° Fah.
1.....	.300	.289	.300	1251	.....	1328	1438	4.22	.....	4	3.7	3.76	.....	.66	.61
2.....	.284	.258	.284	1121	.....	1069	1289	4.72	.....	5	4.1	4.19	.....	.81	.68
3.....	.259	.229	.259	942	.....	835	1072	5.65	.....	6.3	4.9	5.04	.....	1.04	.81
4.....	.238	.204	.238	787	.....	662	905	6.70	.....	8	5.8	5.97	....	1.31	.96
5.....	.220	.182	.220	673	.....	526	774	7.87	.....	10	6.8	6.99	.....	1.65	1.13
6.....	.203	.162	.203	573	.....	417	659	9.17	.....	12.6	8	8.21	.....	2.08	1.32
7.....	.180	.144	.180	450	.....	330	518	11.25	.....	16	10.2	10.44	.....	2.63	1.65
8.....	.165	.129	.165	378	..	262	435	13.89	.....	20	12.1	12.42	.....	3.32	2.
9.....	.148	.114	.148	305	.....	208	350	17.25	.....	25	15.1	15.44	.....	4.13	2.49
10.....	.134	.102	.134	250	.....	165	287	21.29	.....	32	18.4	18.83	.....	5.17	3.04
11.....	.120	.091	.120	200	.....	131	230	27.03	.....	40	22.9	23.48	.....	6.48	3.79
12.....	.108	.081	.109	165	163	103	190	32.21	32.4	50	27.8	28.46	39.36	8.2	4.59
13.....	.095	.072	.095	125	.....	82	144	41.65	.....	64	36.6	37.47	.....	10.39	6.04
14.....	.083	.064	.083	96	98	65	110	45.51	55.6	81	48	49.08	67.88	15.12	7.91
15.....	.072	.057	.072	.....	....	51	83	.....	.....	102	63.7	65.23	.....	16.55	10.5
16.....	.065	.051	.065	.....	55	41	67	.....	96.	126	78.2	80.03	110.70	20.7	12.9
17.....	.058	.045	.058	.....	.....	32	54	.....	.....	162	98.2	100.50	.....	26.5	16.2
18.....	.049	.040	.049	.....	.....	26	38	.....	.....	208	137.6	140.80	.....	33.7	22.7
19.....	.....	.035	.042	.....	.....	20	28	.....	.....	256	187.3	.. ..	.....	41.5	30.9
20.....	.....	.032	.035	.....	.....	16	20	.....		323	269.7	.....	.....	52.5	44.5

BREAKING WEIGHTS.

ENGLISH SYSTEM.

Numbers B & S Gauge	Diameter in Mils.	Breaking Weight Hard Drawn Copper. Pounds	Breaking Weight "Phono-Electric." Pounds
0000	460	8310	11460
000	409.6	6580	9140
00	364.8	5226	7400
0	324.9	4558	6300
1	289.3	3746	5250
2	257.6	3129	4180
3	229.4	2480	3360
4	204.3	1967	2700
5	181.9	1559	2080
6	162	1237	1680
7	144.3	980	1350
8	128.5	778	1075
9	114.4	617	850
10	101.9	489	685
11	90.74	388	545
12	80.81	307	420
13	71.96	245	340
14	64.08	193	270
15	57.07	153	220
16	50.82	133	180
17	45.26	97	135
18	40.30	77	107

ELASTIC LIMIT.

Wire.	Numbers B & S Gauge	Diameter in Mills.	Tensile Strength. Pounds per Square Inch.	Elastic Limit. Pounds per Square Inch.
Hard Drawn Copper...	00	364.8	52000	41775
"Phono-Electric"	00	364.8	73500	57860
Hard Drawn Copper...	0	324.9	54000	39645
"Phono-Electric"	0	324.9	76500	55195

Length of Belting for Various Purposes.

$$\text{Open belting: } L = \frac{\pi}{2} S. + 2C. \left(1 + \frac{1\,D^2.}{8\,C^2.}\right.$$

L = Length of belt.
S = Sum of pulley diameters.
C = Distance between centers of pulleys.
D = Difference of pulley diameters.
π = 3.141592, or, for practical purposes, 3.1416.

For calculating the length of belting approximately, add one-half the circumference of each pulley to twice the distance between centers of the pulleys.

To find the horse-power strength of double leather belting when:

d. = diameter of small pulley in inches.
r. = revolutions of small pulley per min.
b. = breadth of belting in inches.
H.P. = horse-power to be transmitted.

$$\text{H.P.} = \frac{d \times r \times b}{1925}$$

"Double" belting is expected to transmit twice that of "single" belting, and "light double" one and one-half times that of "single."

Strength of wrought iron or steel shafting. (Formula as used by Pencoyd Iron Works.)

$$d = \sqrt[3]{\frac{50 \text{ h. p.}}{R}} \text{ for bare shafts, or H. P.} = \frac{Rd^3}{50}$$

$$\text{or } d = \sqrt[3]{\frac{70 \text{ h. p.}}{R.}} \text{ for shafts carrying pulleys, etc.,}$$

$$\text{or H.P.} = \frac{Rd^3}{70}$$

$$l = \sqrt[3]{720\,d^2} \text{ for bare shafts, or } d = \sqrt[2]{\frac{l^3}{720}}$$

$$\text{or } l = \sqrt[3]{140\,d^2} \text{ for shafts carrying pulleys, etc..}$$

$$\text{or } d = \sqrt[2]{\frac{l^3}{140}}$$

H.P. = horse-power transmitted.
d = diameter shaft in inches.
R = revolutions per minute.
l = length between supports in feet.

To find the horse-power of engines:

in which:

H.P. = indicated horse-power.
Ps = travel of piston in feet per minute.
A = area of piston in square inches.
M. E. P. = mean effective pressure in pounds per square inch.
Ip = initial pressure.

and:

$$(a)\ \text{M. E. P.} = \frac{34 \times Ip}{57} \qquad \text{at } \tfrac{1}{4} \text{ cut off.}$$

$$(b)\ \text{M. E. P.} = \frac{11 \times Ip}{13} \qquad \text{at } \tfrac{1}{2} \text{ cut off.}$$

An application of these formulæ in an appropriate example may be considered in the following problem:

It is desired to determine the I. H. P. of an engine whose cylinder is 10 inches in diameter and whose stroke is 12 inches, operating at 300 revolutions per minute, the initial steam pressure being 100 pounds per square inch, cutting off at ¼ and ½ stroke, respectively:

$$(a)\ \text{M. E. P.} = \frac{34 \times \text{Ip}}{57} = \frac{34 \times 100}{57} = 59.65 \text{ at } \tfrac{1}{4}$$

cut off.

$$(b)\ \text{M. E. P.} = \frac{11 \times \text{Ip}}{13} = \frac{34 \times 100}{13} = 84.6 \text{ at } \tfrac{1}{2}$$

cut off.

$$\text{A} = \frac{\text{n}}{4} \times \text{diameter}^2 = .7854 \times 10^2 = 78.54 \text{ square inches.}$$

Ps = .2 feet per revolution and 300 revolutions per minute = 600 feet per minute.

$$\text{I. H. P. at } \tfrac{1}{4} \text{ cut off} = \frac{\text{Ps} \times \text{A} \times \text{M. E. P.}}{33{,}000} =$$

$$\frac{600 \times 78.54 \times 59.65}{33{,}000} = 85.18$$

$$\text{I. H. P. at } \tfrac{1}{2} \text{ cut off} = \frac{\text{Ps} \times \text{A} \times \text{M. E. P.}}{33{,}000} =$$

$$\frac{600 \times 78.54 \times 84.6}{33{,}000} = 120.8$$

To find the horse-power of a pulley:

Multiply the circumference of the pulley in feet by the revolutions per minute, and the product thus obtained by the width of the belt in inches, and divide the result by 600.

This rule is founded on the fact that good, ordinary, single leather belting, with a tension of fifty-five pounds per inch width, will require fifty square feet of belt surface passing over the pulley per minute for one horse-power. Fifty square feet per minute is equal to a belt one inch wide running 600 feet per minute.

To find the speed of a belt, multiply the circumference of the driving pulley in feet by the revolutions per minute.

Belts should always be run with the *grain* side next to the pulley.

Rule for finding size of dynamo driving pulleys.

$$d = \frac{D \times S}{S^1}$$

d = required diameter of dynamo pulley.
D = diameter of engine pulley.
S = number of engine revolutions per minute.
S^1 = required revolutions of armature per minute.

The light cut-off by arc lamp globes is

Ordinary glass	10%
Light ground glass	30%
Heavy ground glass	45 to 50%
Strong opal glass	50 to 60%

STANDARD SYMBOLS FOR WIRING PLANS

AS ADOPTED AND RECOMMENDED BY

THE NATIONAL ELECTRICAL CONTRACTORS ASSOCIATION OF THE UNITED STATES.

Ceiling Outlet; Electric only. Numeral in center indicates number of Standard 16 C. P. Incandescent Lamps.

Ceiling Outlet; Combination. ½ indicates 4-16 C. P. Standard Incandescent Lamps and 2 Gas Burners.

Bracket Outlet; Electric only. Numeral in center indicates number of Standard 16 C. P. Incandescent Lamps.

Bracket Outlet; Combination. ½ indicates 4-16 C. P. Standard Incandescent Lamps and 2 Gas Burners.

Wall or Baseboard Receptacle Outlet. Numeral in center indicates number of Standard 16 C. P. Incandescent Lamps.

Floor Outlet. Numeral in center indicates number of Standard 16 C. P. Incandescent Lamps.

Outlet for Outdoor Standard or Pedestal; Electric only. Numeral indicates number of Stand. 16 C. P. Incan. Lamps.

Outlet for Outdoor Standard or Pedestal; Combination. ½ indicates 6-16 C. P. Stand. Incan. Lamps; 6 Gas Burners.

Drop Cord Outlet.

One Light Outlet, for Lamp Receptacle.

Arc Lamp Outlet.

Special Outlet, for Lighting, Heating and Power Current, as described in Specifications.

Ceiling Fan Outlet.

S' S. P. Switch Outlet.
S² D. P. Switch Outlet.
S³ 3-Way Switch Outlet.
S⁴ 4-Way Switch Outlet.
S⁵ Automatic Door Switch Outlet.
Sᴱ Electrolier Switch Outlet.

Show as many Symbols as there are Switches. Or in case of a very large group of Switches, indicate number of Switches by a Roman Numeral, thus; S⁵ XII; meaning 12 Single Pole Switches.

Describe Type of Switch in Specifications, that is, Flush or Surface, Push Button or Snap.

Meter Outlet.

Distribution Panel.

Junction or Pull Box.

Motor Outlet; Numeral in center indicates Horse Power.

Motor Control Outlet.

Transformer.

Main or Feeder run concealed under Floor.

Main or Feeder run concealed under Floor above.

Main or Feeder run exposed.

Branch Circuit run concealed under Floor.

Branch Circuit run concealed under Floor above.

Branch Circuit run exposed.

Pole Line.

Riser.

Telephone Outlet; Private Service.

Telephone Outlet; Public Service.

Bell Outlet.

Buzzer Outlet.

Push Button Outlet; Numeral indicates number of Pushes.

Annunciator; Numeral indicates number of Points.

Speaking Tube.

Watchman Clock Outlet.

Watchman Station Outlet.

Master Time Clock Outlet.

Secondary Time Clock Outlet.

Door Opener.

Special Outlet; for Signal Systems, as described in Specifications.

Battery Outlet.

Circuit for Clock, Telephone, Bell or other Service, run under Floor, concealed.
Kind of Service wanted ascertained by Symbol to which line connects.

Circuit for Clock, Telephone, Bell or other Service, run under Floor above, concealed
Kind of Service wanted ascertained by Symbol to which line connects.

NOTE—If other than Standard 16 C. P. Incandescent lamps are desired, Specifications should describe capacity of Lamp to be used.

SUGGESTIONS IN CONNECTION WITH STANDARD SYMBOLS FOR WIRING PLANS.

Indicate on plan, or describe in specifications, the height of all outlets, located on side walls.

It is important that ample space be allowed for the installation of mains, feeders, branches and distribution panels.

It is desirable that a key to the symbols used accompany all plans.

If mains, feeders, branches and distribution panels are shown on the plans, it is desirable that they be designated by letters or numbers.

ELECTRICAL INJURIES

By Charles A. Lauffer, M.D.,

Medical Director, Relief Dept., Westinghouse Company.

The usual injuries encountered in the industrial applications of electricity are due to exposure to flashes and to actual contact.

SYMPTOMS OF FLASHED EYES.

Eyes which have been exposed to electrical flashes become very red, due to the sudden dilation and congestion of the blood vessels of the mucous membrane lining the lids and in part covering the eyeball, known as the conjunctiva; such an inflammation of it constituting a conjunctivitis. The pain is intense, there is an aversion to light, and a copious secretion of tears.

Often the eyelashes and eyebrows are singed, and charred hair, skin débris and dust particles may fill the eyes, contributing to the severity of the above symptoms.

In the more severe case, in addition to the conjunctivitis, there may appear around the central transparent area of the eyeball, known as the cornea, a zone of red; such a zone of red in the white of the eye, near its junction with the colored part of the eye, known as the iris, constitutes an iritis. It is characteristic of a congestion of the blood vessels within this portion of the eyeball. If the heat of the flash is sufficient, as in the more severe cases, the superficial layers of the transparent cornea are coagulated.

TREATMENT OF FLASHED EYES.

The immediate treatment consists in washing the region of the eye and the eyelids with eye-water, then washing the eye itself. A serviceable formula for eye-water is as follows:

℞ Sodii biboric 0.30
Acidi boric 0.15
Alumini sulphatis 0.06
Zinci sulphatis 0.06
Aquæ Camphoræ .....30.

Sig. Use freely as an eye-wash.

Upon dropping into the eyes a sufficient quantity of three per cent. cocaine hydrochloride solution, the débris may be mopped out with clean cotton wrapped on a toothpick. The coagulated tissue of the cornea is similarly mopped off.

The immediate relief of pain is secured by cold compresses over the eyes, and the chief remedy in the subsequent tratment is cold compresses; merely cotton or a clean cloth laid on ice, or made wet in ice water, and changed by the patient every two minutes. The cold compresses serve to contract the dilated blood vessels, and thus control the painful congestion. They can be employed for an hour at a time, as the patient lies down; not constantly, but every other hour. This enables the patient to get some sleep, for flashed eyes are most painful, when he is relaxed and ready to sleep. Eye-water is used every hour. In severa cases adrenalin hydrochloride, 1:5000 solution, is used every half hour; atropine sulphate, one per cent. solution, a few drops every four hours to control the iritis referred to above, if this symptom manifests itself. Also it may be necessary to apply castor oil every two hours to prevent the evelids and eyeballs from growing together (synechial adhesions) if the corneal tissue has been much injured. In the milder flashes the three latter remedies are omitted, as the patient wears smoked glasses and returns to work in two or three days. Recovery is prompt and complete in practically all cases.

It is conceivable that high intensity flashes are capable of seriously affecting the optic nerves in susceptible cases, though such a case has never

come under our observation. The fire of the flash that singes the hair or burns the skin is but one element in the production of this type of injuries, as eyes may be "flashed" and present the congestion, lachrymation, pain and aversion to light (the cardinal symptoms of flashed eyes) when the person is too remote from the heat of the flash to be burned. The intense light of the electric welding arc will produce a similar conjunctivitis and iritis; the effect probably being due to the ultra-violet rays present in the electric arc. However, the red and blue glasses worn in the helmets of the welders protect them from the high intensity light.

SYMPTOMS OF FLASHED SKIN.

Flash burns of the skin are usually burns of the second degree. That is to say, while destroying the outer layer of the skin (the epithelium) they do not injure the inner layer of the skin (the corium) nor the deeper tissues. At first these burns may present a mere congestion; the skin is red, as from exposure to the sun, and they have the appearance of a first degree burn, scarce worth while dressing and bandaging. But there is pain, some redness, and by the second day huge blebs or blisters may have formed. Usually the hair is scorched; often the outer skin is blown off, and the surface looks ragged. Under proper treatment of these cases there is seldom any formation of pus, and they will heal up, usually without leaving a scar. We have treated many of such burns with the happiest results. We have treated men whose features were so altered by burns and the eyes so swollen shut, that their own mothers would not have known them. To the uninitiated it seemed they were scarred for life, yet within two weeks they were able to resume work, and within two months no trace of their burns was discernible.

TREATMENT OF FLASH BURNS OF THE SKIN.

The immediate treatment of flash burns consists

in securing the highest obtainable degree of surgical cleanliness with ethereal soap applied with numerous cotton sponges (using sterilized absorbent cotton such as is sold for medical uses) and the application of sterile gauze dressing, well covered with Unguentine. A good formula for ethereal soap that dissolves and removes the dirt and grease at the same time rendering the area antiseptic consists of:

Sulphuric ether	4 oz.
Turpentine	1 oz.
Alcohol	3 pts.
Surgical soft soap	4 lbs.
Water, enough to make	1 gal.

We find this ointment uniformly reliable; it soothes the pain and promotes recovery. A loose gauze bandage is applied and the part put at rest.

The subsequent treatment consists of daily redressings. When the blebs are large, we scissor them open freely, but allow the outer skin to remain for some days, as it is in itself a splendid protective covering.

These burns must be washed clean, then there is little liability to infection with its pain, the formation of pus, and the resulting long term of disability. But should it become infected and pus form, we at once trim away the skin débris, so as to allow no pockets for the retention of infection. In the absence of infection; that is, when the pus-producing bacteria do not invade the wound, the dead skin is removed within a few days, after the inner senstive layer of the skin has had a chance to harden somewhat, and to lose its hypersensitiveness. When the healing has progressed we sometimes apply ten per cent. Ichthyol in Petrolatum, to facilitate the formation of normal skin. After recovery, in most cases, the skin remains red and sensitive for some weeks. We instruct the patient to wear canvas gloves and otherwise protect the new skin

from grime and weather, as it is prone to eczema.

The dry, open method of treating such burns, namely, that of powdering on Stearate of Zinc freely and exposing them unbandaged to the air, is more or less successful in hospital practice, but not adapted to ambulatory patients, especially those that may live on the streets and in dirty houses, and who may return to work before complete recovery.

SYMPTOMS OF FLASHES FROM HIGH VOLTAGE.

In contrast to the usual benign burns from low voltage is the severe burning from high voltage flashes, causing destruction of all layers of the skin (third degree burns) over large areas. Great mental excitation, even transient mania, is sometimes observed in these cases; again, on the contrary, some patients are relaxed, unconscious, not breathing, and may require immediate resuscitation by artificial respiration.

TREATMENT OF HIGH VOLTAGE FLASHES.

These are hospital cases, and they may require much care to ensure their recovery. Delirium is sometimes encountered. Where large areas are burned there is incrased danger from sepsis. When convalescence is established, skin deficiencies are restored by grafting. In such cases the recovery is slow. Scarring will be more or less extensive, depending on the depth and extent of the burns and the infection that may be associated.

PREVENTION OF ELECTRICAL FLASHES.

Careful attention in handling switches and plugs is imperative. Circuits should be opened whenever practicable during tests and in repair work, and danger signs erected, as well as isolating the test by means of ropes. In repairing of transmission lines and transformers connected thereto, the lines should be thoroughly grounded at the point of repair on any side from which power may accidently be thrown on. Attention to such details as every electrician knows, but sometimes ignores, will do much

to minimize the number of these injuries. With sleeves rolled up to the elbows, no gloves, and the face near a switch when it is opened on a circuit carrying a heavy load, the exposure to flash burns is unnecessarily increased.

Great caution should be observed in approaching live high voltage conductors, and a safe distance maintained. Even the high voltage of switchboards has been known to jump some distance, envelop a man in its flaming discharge, seriously burn him, and violently throw him down. High voltage should never be disregarded under any circumstances. It should be respected.

CAUSATION OF FLASH INJURIES.

Flashes of arcs occur upon breaking or momentarily short-circuiting, direct and alternating current, as, for example, where a switch in a heavily loaded circuit is opened by mistake, where wires with deficient insulation become crossed, or where a workman at a switchboard allows his screwdriver to slip, causing a short circuit. A score of ways there are that will cause a sheet of flame to issue forth, surprising even the experienced, but more often the novitiate.

Although electrical flashes are of but momentary duration, the heat developed is often very great. This great heat will produce painful burns of the unprotected skin and eyes. Similar burns may also result from continued exposure to the rays of the electric arc as is used in welding, though the operator may not have been near enough to feel any intense heat. Such burns usually do not become apparent till several hours after the exposure. Eyes can be flashed by the welding arc at a considerable distance.

Such is the origin of the mild flashes ordinarily observed and readily amenable to treatment; then there are the severe burns from high voltage conductors.

With a voltage much in excess of 15,000, a man seldom makes contact, for the voltage jumps over to his fingers, flexing them, and making it impossible to make contact; 33,000 volts will leap through ordinary insulation and go to the man who approaches it. The discharge is instantaneous and takes place before he can make actual contact with the conductor, unless he is thrown upon it. On this account there is less liability to contact burns from high voltage than from low voltage. The discharge that bridges the interval between the circuit and its victim may cause extensive face burns. Such a flash is but a leakage from the high voltage conductor, and to the extent that it spends its force on the surface, there is diminished liability of serious electrical shock.

The man approaching the high voltage conductor sinks as if shot when the discharge strikes him. Although the conditions may be such that he will receive a heavy current, the discharge may carry with it only a small current, yet enough to flex his arm and leg muscles (the flexors are stronger than the extensors) and cause him to fall all over himself. Such precipitation assists in extricating him from what might be a dangerous contact, whereas in a lower voltage, with hand grasping the conductor, the excessive electrical stimulation of his muscles causes his grip to tighten; his fingers flex tetanically; he is unable to release his hold.

The flashes from high voltage may moreover carry sufficient current to cause a suspension of animation—to be considered later.

CONTACT INJURIES.

The two types of contact injuries are shocks and burns. The passage of an electric current through the human body may cause a momentary unpleasantness, the retention of the victim within the circuit unable to release himself, a suspension of consciousness, during which he falls, but revives again,

or a suspension of animation, requiring artificial respiration.

RESUSCITATION BY ARTIFICIAL RESPIRATION.

The efforts at resuscitation must be begun the instant the patient is freed from the contact. Sixty seconds is too long for preliminaries. The comrade nearest him must know how to give artificial respiration, as loss of time in summoning a physician is unpardonable. The services of the latter is often essential in winning back a life near extinguished, but the artificial respiration must be begun early, and perseveringly continued, if the life is to be saved.

While the heart beats there is hope. Artificial respiration helps sustain the cardiac action. Even when no radial pulse is felt, the comrades are not justified in ceasing their efforts at resuscitation, as the heart may still be beating feebly. In those occasional cases, where the heart action has ceased, as the physician upon his arrival may determine with his stethoscope, there will be no possibility of restoring the normal respiration by any method of artificial respiration. Yet the victim should have the benefit of any doubt, for there are few cases of accidental electrocution where the victim cannot be restored from the electrical shock, if appropriate immediate efforts at resuscitation are instituted.

RULES FOR ARTIFICIAL RESPIRATION.

The three essentials of the Prone Pressure method of artificial respiration to be remembered and practiced in anticipation of an emergency:

I.—The man is laid upon his stomach, face turned to one side, so that the mouth and nose do not touch the ground.

II.—The operator kneels, straddling the patient's hips, or kneels by either side of the hips, facing the patient's head.

III.—The operator places his spread hands upon the lower ribs of the patient and throws his own

body and shoulders forward, so as to bring his weight heavily upon the lower ribs of the patient.

The operator's downward pressure should occupy about three seconds, then his hands are suddenly removed. Squeezing the chest in this manner forces the air out of the lungs. On release of the pressure the elasticity of the chest walls causes them to expand, and the lungs are refilled with fresh air. This act should be repeated an indefinite number of times at the rate of twelve times a minute. In the excitement of the occasion the danger is that the rate will be too rapid. If the operator is alone with the patient he can adjust the rate of giving artificial respiration by his own deep, regular breathing: if more persons are present, a watch can be used to advantage to regulate the rate.

Any evidence of returning animation should encourage the operator to continue his efforts. It often requires one-half hour to two hours. In electrical shock seldom over one-half hour, but in cases of drowning, especially, it is advisable to keep at it, for recoveries are alleged to have resulted after three hours of continuous artificial respiration.

SUPPLEMENTAL EFFORTS.

If the operator is alone with the patient, the artificial respiration is his chief concern, and offers the only hope for the victim. Yet if others are present they may keep the crowd back, loosen tight neck bands, if any, and hold a cloth saturated with Aro matic Spirits of Ammonia near the nose. As a respiratory stimulant it is even more useful than oxygen, yet is valuable only as an adjunct to the artificial respiration.

The physician upon his arrival, should the respiratory function continue in abeyance, may render great assistance by the hypodermic administration of Atropin Sulph. gr. 1-100 and Strychnin Sulph. gr. 1-30, which can be repeated at his discretion, or he can stretch the Sphincter Ani.

Injudicious assistance is often harmful. No liquids should be given by the mouth to an unconscious patient. Under conditions met with in electrical shock, and in those near-drowned, liquids given are more liable to enter the lungs than the stomach.

When the rhythm of the respiration is re-established and consciousness is restored, the patient may experience thirst and may be encouraged to drink a teaspoonful of Aromatic Spirits of Ammonia in one-half glass of water,, and the same repeated after a short interval. He may be cold and weak and in that case will require blankets and artificial heat; or he may be strong as ever, in which case it helps wake him up to allow him to walk with assistance, a reasonable distance to the physician to have his accompanying burns dressed.

Yet a word of caution is here necessary. When artificial respiration has succeeded and the patient is recovering from the electrical shock, he may be excited and may desire to stand up too soon. He must be dissuaded from doing so until fully out of the shock—his heart and breathing fully restored—before he is permitted to sit up, and finally stand up. He needs watching for some time. If he gets up too soon a second effort at artificial respiration may be unavailing; it may be the collapse of heart failure.

FORETHOUGHT.

Suspended animation requires instant relief; yet so often many who have been trained to give artificial respiration are helpless in such an emergency. Many are excited, frenzied; all turn white. Some jump up and down, others scream, and are incapable of intelligent action. With deliberate, prudent forethought, akin to the German Bureau of Strategy, each individual must study out in advance just what he would do under given circumstances—if his home or factory were on fire, or a comrade

were on an electric circuit. Every action must be carefully thought out in advance. Testers should know if the floor is a non-conductor, and should know the location of switches that may be opened, or the methods of pulling a man off by his clothing, or otherwise, in such a manner that the rescuer is safe. Then he must previously study out and know how to give artificial respiration, so that there will be nothing unforeseen, nothing unanticipated, in an apparent calamity that spreads consternation particularly among those not qualified to meet the responsibilities of the situation.

ADVANTAGES OF PRONE PRESSURE METHOD.

We adopted the Prone Pressure method because: (1) It is easy to learn. Any intelligent man man can be shown in a few minutes, and can practice on his friends, and they on him, until he becomes an expert in the art of giving artificial respiration. (2) It requires no apparatus. There is no delay due to waiting until an emergency outfit is found. (3) It can be carried on easily by one person. A mere boy of twelve can resuscitate an overweight adult and maintain sufficient inflow and outflow of air (tidal air), as much as he would secure were he able to breathe voluntarily. One operator can work without exhaustion for an unlimted length of time by this method; there is no need of team work, and teams working in relays, as for example with the Sylvester-Laborde method. Hence, there is diminished temptation to quit too soon. (4) Spirometer tests show the Prone Pressure method superior, as exhibited by Prof. E. A. Schafer, of Edinburgh, before the American Medical Association. (5) It is the method that best meets the complications of suspended animation as encountered in electrical shock: (a) In the usual excessive relaxation of electrical shock, there is great liability of swallowing the tongue with the patient on the back, and considerable difficulty in holding

it forward; by the prone pressure method, with the man on his stomach, the tongue falls forward of its own weight. (b) In the frequent bronchorrhœe (excessive secretion from air-passage) and edema of the lungs (leakage of bloodstained serum into air-vesicles) by laying the man prone on his stomach, these secretions run out of the mouth, and there is no danger of drowning the man in his own secretions. By the older method, where this complication was successfully met, the patient had to be rolled on his stomach occasionally to permit of the escape of bloody mucus, then rolled on his back, and the secretions churned up in his lungs until the artificial respirations are another time interrupted by rolling him on his abdomen to let the secretions escape from his mouth. (c) In cases of electrical shock presenting muscular rigidity a continuous rigid contraction of the muscles, tetanic. his arms cannot be manipulated; by pressure on the ribs, acocrding to the prone pressure method, and simultaneous pressure on the abdomen by a second comrade, mucus is expelled from the mouth within a brief period, and with the first forced expiration there comes a general muscular relaxation and continued artificial respiration leads to recovery.

THEORIES OF ELECTRICAL SHOCK.

Physiological experimentation on animals adduces the conclusion that in suspended animation (cessation of respiration and cardiac action) from electrical overstimulation the brain loses its power to react to stimuli. This irritability (power to react), is only temporarily suspended, so that life, if not entirely extinct, is dependent on artificial respiration until such time as the brain (the central station) recovers its irritability.

Like the dry cell battery of a common door bell, which, if rung too continuously, ceases ringing; so the brain, if over-stimulated to the point of exhaustion, suspends vital operations. The dry cell

left to itself recovers, and the bell will ring again; the brain possesses infinitely greater power of recovery. But artificial respiration must be employed to supply oxygen, so that oxygenated blood may help sustain the cardiac function, else there will be no interval of rest allowed the exhausted brain in which to recover.

While the irritability of the brain, which subsides immediately after the shock, will within a few minutes recover, everything depends finally, where artificial respiration is employed, on whether the action of the heart continues or not.

A second theory is that of asphyxiation, or the non-oxygenation of the blood. There is heightened chemical activity from the current that induces the electrical shock and much carbon dioxide is produced.

The excess of carbon dioxide in the blood paralyzes the respiratory center of the medulla. In asphyxia artificial respiration is required, and must be continued until the blood is oxygenated, before the normal respiratory function will be re-established.

A third theory makes electrical shock depend upon a sudden dilatation of the great vessels of the splanchnic area. The blood vessels are held in a state of tonic constriction by nerves of the sympathetic nervous system. The shock is conveyed from the cerebro-spinal nervous system to the sympathetic. This tonic constriction of the splanchnic vessels (those of the abdominal viscera) is suddenly recalled, suppressed, and in a moment these vessels dilate to twice their normal diameter, able to contain four times the quantity of blood normally contained, and the man in shock is liable to die of hemorrhage into his own vessels. Paradoxically, he can die of hemorrhage in this state without shedding a drop of blood.

Respiration will cease at once from anemia of

the medulla; the brain depends for its blood tension on the tonicity of the vessels of the splanchnic area. Not only will the brain be without blood, but the heart will have no blood to impel into the arteries, and unless artificial respiration is resorted to instantly, the increasing asphyxia will speedily result fatally.

I believe that all three theories are interdependent, and that in addition there may be other factors.

SYMPTOMS OF CONTACT BURNS.

The burns from electrical contact are generally of the third degree; that is, there is a destruction of both layers of the skin, and even of the deeper tissues. The real extent is not immediately apparent. The tissues are coagulated, and there is a deep white slough that is slow in separating. At times, fingers are burned to a cinder, or the vascular supply so destroyed as to cause a dry gangrene. These burns are as a rule painless, and upon recovering from the shock the patient may not consider himself burned, but later the discovery is made. In the milder forms they may not report for treatment until some days after the accident, by which time the burn has become infected. But these burns are worse than they look and are obstinate to heal, especially after infection sets in. Ordinarily, in the milder cases, the patient is best treated while continuing at work. In the severer degrees, as above mentioned, they are hospital cases.

TREATMENT OF CONTACT BURNS.

The immediate treatment in case of such burns consists in surgical cleanliness, secured by ethereal soap applied with numerous cotton sponges. For the milder burns, we prefer Depletol, or 10 per cent. ichthyol on sterile gauze, to facilitate the separation of the necrosed (dead, tissues. When the slough has separated, we commonly employ balsam of Peru as a dressing, and alternate with thymol iodide at times. When crusts form under this mode

of treatment, we employ zinc oxide ointment, to remove them, and continue the daily dressings until the defect has granulated in and the area is covered with healthy skin.

The severer burns in hospital practice are treated by open, dry or wet methods, in accordance with the ideas of the surgeon on the particular service. It is customary to be conservative in waiting for gangrene to demark the necrosed tissues, rather than to resort to immediate amputation, inasmuch as the boundaries of the damaged tissues cannot be immediately determined. Burns of the palms which to the uninitiated may seem trivial, may necessitate the amputation of the hands, due to necrosis of the tendons.

FACTORS IN CAUSATION OF CONTACT BURNS.

There is a wide variety of external and individual conditions that influence the extent of electrical injury, and there is an interdependence of circumstances that make tabulated results and reports of accidents apparently inconsistent. At one time 110 volts are involved, and there is a fatal accident; at another time 15,000 and recovery will ensue.

The voltage being equal, alternating current is probably less dangerous than direct current. With alternating-current frequencies below 50,000 cycles, and equal voltage, more response is produced than in frequencies approaching 100,000 cycles per second.

High frequency currents, even though of high voltage, such for example as are produced by X-ray, induction coils, and also that of wireless telegraph apparatus, are not ordinarily dangerous, on account of their tendency to seek the surface of conductors in their circuit, rather than flow by way of internal path.

While burns and electrical shock are often associated, it is noteworthy that in many cases of acci-

dental electrocution, there are no demonstrable burns.

Tabulated figures on the electrical resistance of the human body varies greatly. For example, by the bridge method on the Baker Static Machine the hand to hand resistance on various individuals was found to be 40,000 ohms (min.) to 140,000 ohms (max.). Moistening the hands cuts the hand to hand resistance to 29,000 ohms, immersing the hands in water reduces it to 5,400 ohms, and making the water conductive by the addition of salt, further reduces it to 4,600 ohms.

While approximately 15 ampere of current is used for criminal electrocutions, with electrodes at base of brain and calves of legs, yet 1/10 ampere may become dangerous under certain conditions of contact, and ½ ampere is considered prohibitive.

A current that is harmless at first, by breaking down the skin resistance and taking an internal path, may become dangerous.

The location and number of contacts is an important factor, as well as the duration of the contact. "A small current applied over the pneumogastric nerve in the neck would paralyze the heart, whereas taken through the hands or body, the path must be over the nervous mechanism controlling the respiratory and cardiac centers to produce death." But it can be argued the electric current follows the blood vessels, not the nerve trunks; oil is a con-conductor, the nerve trunks are chiefly fat, the saline constituents of the blood make it a good conductor.

Panic (the emotions), causing profound vasomotor paresis and vascular dilatation from slight injury, and subsequent failure in performing artificial respiration, probably accounts for many deaths. A defective heart is also a possible cause of death, where there are fatalities and little current is involved.

It can be contended that electric current does not kill in most of the deaths attributed to it. Some of these deaths are undoubtedly the result of neglect; resuscitation is delayed, improperly conducted, or discontinued too soon. An electrician in our plant within six years in his own department has rescued six from death's door, six out of six, a record of 100 per cent. saved. He is there within three seconds, and begins the artificial respiration in the spot where they fall, and keeps by them in that spot until they have fully recovered. He is enthusiastic for the prone pressure method.

This outline sketch of electrical injuries is designed to emphasize the curability of this type of accidents, and to encourage everybody to learn how to give artificial respiration by the prone pressure method, with the purpose of minimizing the number of fatalities from electrical shock.

Switchboard and Electrical Fires

A liquid extinguisher called Pyrene has recently been put on the market. Experiment and acceptance tests made by the largest electric light, power, railroad and transit companies in America and by the underwriters laboratories, indicate that it is of great value to the electrical industry. At several of the tests made short-circuit electrical arcs larger than any that have ever before been intentionally produced, were successfully handled by this extinguisher, arcs of an indicated energy of 400-h.p. being snuffed out by a few ounces of the liquid. It was also found difficult to re-establish the arcs when put out by this preparation.

The extinguisher is small and light, working on the principle of a double-acting syringe, can be conveniently located and is easily carried. As the liquid wil not freeze at 60° below zero it can be left in exposed places during the winter. No periodic recharging is required, although they are refillable after use.

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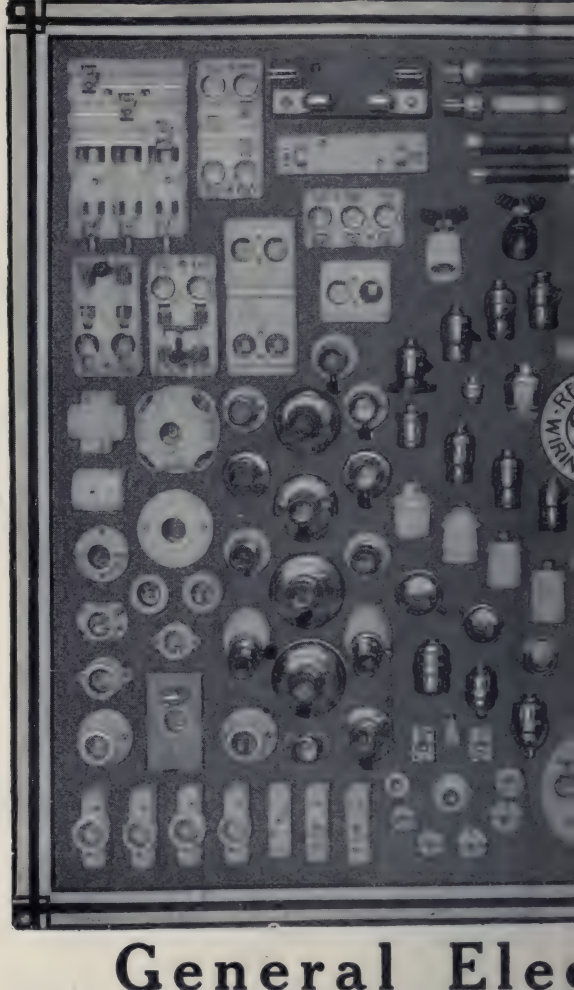

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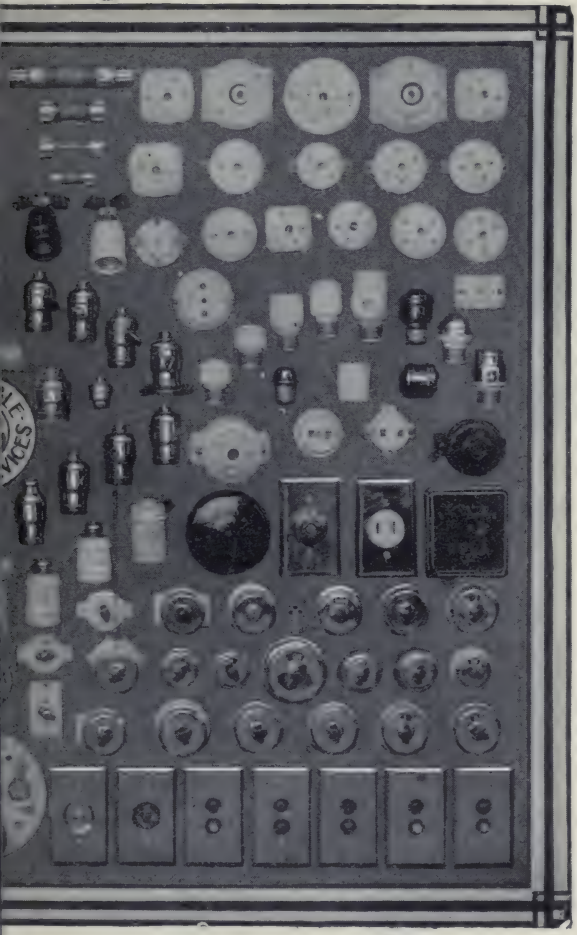

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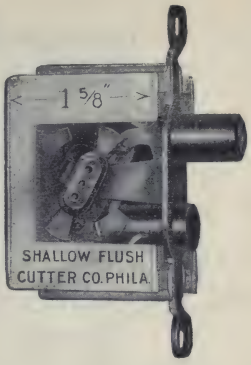

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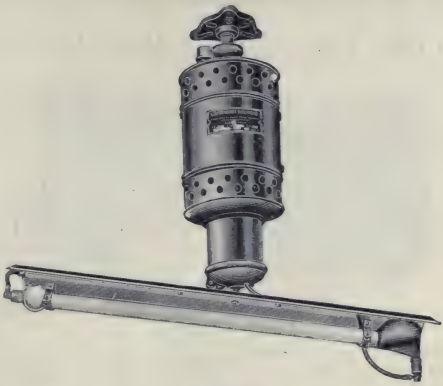

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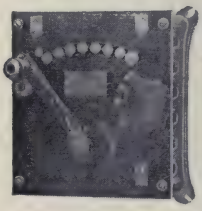

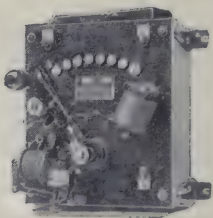

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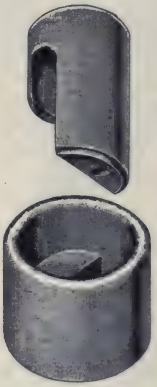


No Slack Wires

It meets with all the requirements of the underwriters and is made for use with No. 8, 10, 12 and 14 wire.

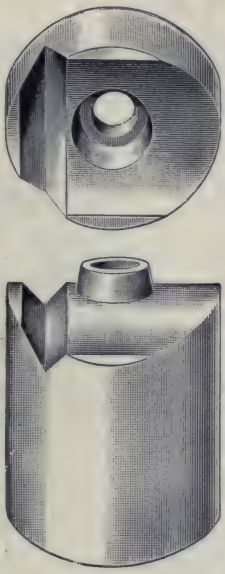
WRITE FOR OUR CATALOGUE AND PRICES

The Star Porcelain Co.

TRENTON, N. J.

The Star Oval Split Insulator

Pat. Dec. 5, 1905



For the use of wire without tying

The oval shape enables the hole to be placed in the center with less material than generally used, and holds the wire securely when in place by means of the curve between the top and bottom.

WRITE FOR OUR CATALOGUE AND PRICES

The Star Porcelain Co.

TRENTON, N. J.

THE COOK WEDGE SPLIT INSULATOR

Makes Standard Wiring Easy

Made of the Best Hard White Porcelain. No Burrs or Rough Edges to cut Insulation, but Firmly Grips the Wire when Screwed in Place—The Cap Needs no Centering. Once Used Never Replaced.

Trial Orders Packed 500 in a Box

Protected by U. S. Patents

Ask Your Jobber or Write Us for Samples and Prices

COOK POTTERY CO., Trenton, N. J.

SOLE MANUFACTURERS

THE

"National" STORAGE BATTERY

IN ANY TYPE FOR EVERY CLASS OF SERVICE

The National Storage Battery is carefully designed and thoroughly built. The conditions of each class of service have been analyzed and a distinctive type has been developed to meet each set of conditions most perfectly. We have aimed to secure the best efficiency and at the same time an exceptional durability so that the maintenance cost is reduced to the minimum. Our special process for making the leaves of the plates gives a distinctive character to our Planté plates.

Manufactured by

The United States Light and Heating Co.

GENERAL OFFICES: 30 Church Street, New York

FACTORY: Niagara Falls, N. Y.

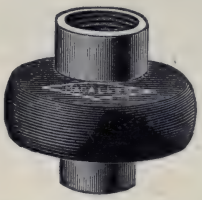
SALES OFFICES AND DEPOTS:

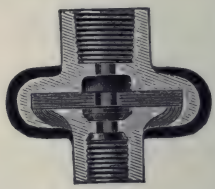
New York Buffalo Detroit St. Louis
Boston Cleveland Chicago

MACALLEN

Solid Mica

Insulating Joints





Regularly inspected and labeled under the supervision of the Underwriters' Laboratories, Inc., under the direction of the National Board of Fire Underwriters.

We carry a large stock and can fill all orders promptly.

The Macallen Company

Macallen & Foundry Streets

Boston, Mass.

Catalogues and Price Lists Furnished Upon Application

MACALLEN
Canopy Insulators

Patented July 13, 1897

Regularly inspected and labeled under the supervision of the Underwriters' Laboratories, Inc., under the direction of the National Board of Fire Underwriters.

They are designed to go between the canopy and the wall, or ceiling, where combination or straight electric fixtures are installed in buildings that are constructed with metallic lathing, or where there are metal ceilings or walls used.

They are made of a special compound that is thoroughly waterproof, strong, durable, and of the highest insulating qualities.

We manufacture these insulators to fit all standard sizes of canopies.

TRADE MACALLEN MARK.

The Macallen Company

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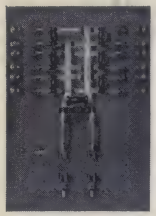
Boston, Mass.

Catalogues and Price Lists Furnished Upon Application

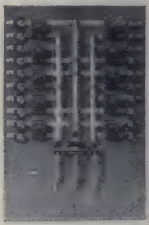
Crouse-Hinds' Products

Panel Boards

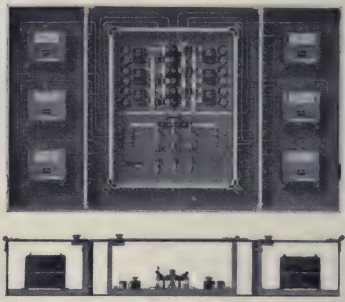
Any Size
Standard or
Special



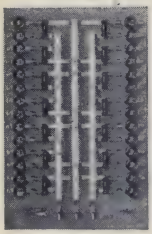
Type "A" Panel



Type "H" Panel

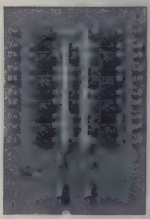


Multimeter Panel



Type "D" Panel

Write for
Catalog
Bulletin No. 1



Type "F" Panel

Crouse-Hinds Company

Syracuse, N. Y., U. S. A.

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Crouse - Hinds' Products

Type "A P" Cabinet

Cabinets

Wood and
Steel
Flush and Surface
Types

Type "A L" Cabinet

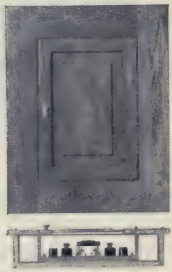
Do Not Order Until You Have Seen

Our Panel Board and Cabinet Catalog, Bulletin No. 1—Free for the Asking

Most Complete and Best Lines Ever Presented

Type "B M" Cabinet

Also
Special
Designs



Type "F F T" Cabinet

Crouse - Hinds Company

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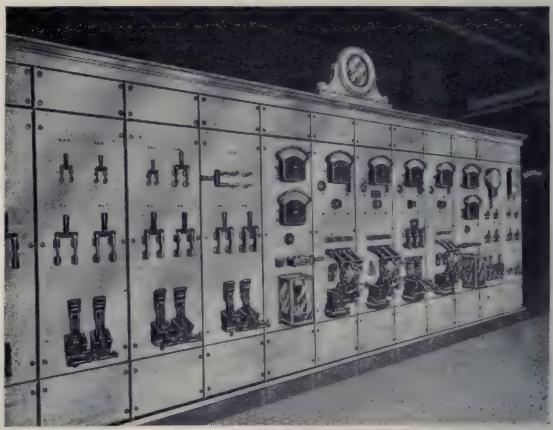
SWITCHBOARDS

STANDARD AND SPECIAL BOARDS

For Direct and Alternating Current



A Crouse-Hinds Switchboard in Court House, Syracuse, N. Y.

LET US KNOW YOUR REQUIREMENTS

Our long experience and facilities insure scientific construction and prompt delivery.

Crouse - Hinds Company

Syracuse, N. Y., U. S. A.

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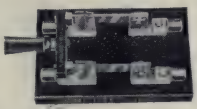
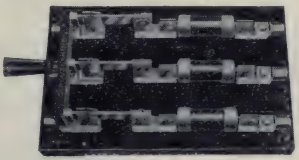
KNIFE SWITCHES

Front and Back Connection

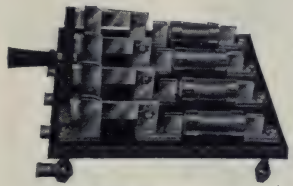
With or without Fuse Terminals. Type "B," all capacities, 0-600 Volts. Also Ammeter and Voltmeter Switches, Ground Detectors. Every one Approved.



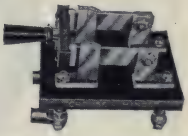
Type "B."—Front Connection Without Fuses



Type "B"—Front Connection Enclosed Fuses



Type "B"—Back Connection Enclosed Fuses



Type "B"—Back Connection Without Fuses

Best that Science and Skill can Produce

Write for Knife Switch Catalog

Crouse - Hinds Company

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Headlights, Guy Anchors and Adjustarods,

Types "A" and "B"

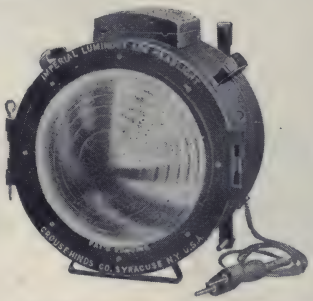
Special designs of HEADLIGHTS, to meet all requirements of Traction Lines, Harbor Service and Mines.

HARPOON GUY ANCHORS, the easiest to install—never loosen

ADJUSTARODS are the only all-in-one metal equipment for "dead man" anchors

Harpoon Guy Anchor (Closed)

Harpoon Guy Anchor (Opened)



Imperial Luminous Headlight—Combination Arc and Incandescent—Type "I. A"

Free Catalogs on Each Product

Type "A" Adjustarod

Type "B" Adjustarod

Crouse-Hinds Company

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Crouse - Hinds' Products

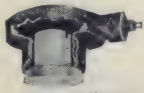
CONDULETS

No Conduit Outlet Without Its Condulet

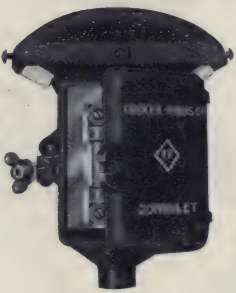
Type "Q H C"

Type "L F"

Type "Q K C"

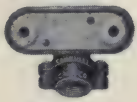


Type "N"



Type "FF"

Type "S"



Type "F"

Type "C H C"

Type "F S"

Type "W"

Type "F S C"

Write for Condulet Catalog, Bulletin No. 100

Crouse-Hinds Company

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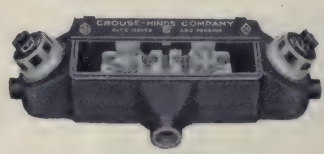
CONDULETS

A Separate Type for Each Requirement

Type "V"



Type "Z D"

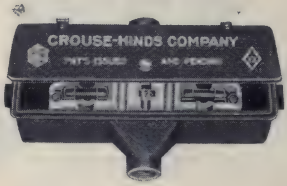
Type "V H C"

Type "P"

Type "Y C"

Type "R"

Type "L L"



Type "Y X"

Type "L R"

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Crouse - Hinds Company

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Crouse - Hinds' Products

CONDULETS

Weatherproof and Especially Adapted for Outlining

Type "J X"

Type "J A"

Type "J T"

Type "K D"

Type "J I,"

Type "K B"

Type "K C"

Type "K"

Type "J"

Type "J B"

Type "K A'

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Crouse - Hinds Company
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Crouse-Hinds' Products

Conduletto Fittings
Made Weatherproof by Gaskets

Receptacle with Shade Holder Groove

Receptacle without Shade Holder Groove

Type "C" Condulet with Conduletto Receptacle (exploded view)

Cord Rosette

Fixture Rosette

Write for Catalogs on Porcelain Fittings

Crouse-Hinds Company

Syracuse, N. Y., U. S. A.

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Crouse - Hinds' Products

Norbitt Specialties

For Condulet, Moulding, Cleat, Conduit Box and Temporary Installations

* Condulet Receptacle with Shade Holder Groove

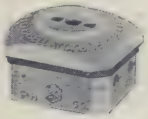
* Moulding Receptacle without Shade Holder Groove

* Conduit Box Receptacle with Shade Holder Groove

Weatherproof Fixture Socket with ⅛ and ¾-inch Female Nipples

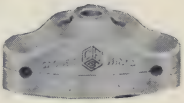
Crouse-Hinds New Temporary Decorative Weatherproof Socket

Weatherproof Socket (Pendant)



Hubbell Attachment Plug Receptacle

Write for Catalogs on Porcelain Fittings



* Cleat Cord Rosette

* This line covers a receptacle with shade holder groove, without shade holder groove, cord rosette and fixture rosette.

Crouse-Hinds Company

Syracuse, N. Y., U. S. A.

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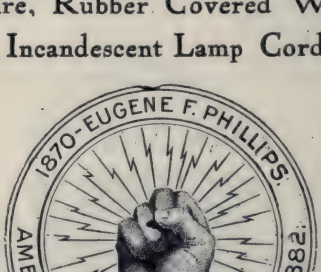
American Electrical Works

Phillipsdale, R. I.

"National Electrical Code Standard"

STAR ★ BRAND

Weatherproof Line Wire, Slow-Burning Wire, Rubber Covered Wire, Incandescent Lamp Cord



Railway Feeder and Trolley Wire
Galvanized Iron Wire and Strands

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176 Federal St.

CHICAGO
112 West Adams St.
CINCINNATI
Traction Bldg.

Montreal, Canada

AMERICAN STEEL & WIRE COMPANY

Chicago **New York** **Denver**
Worcester **San Francisco**

Makers of National Electrical Code
Rubber Covered Wires
Weatherproof Wires
Lead Incased Cables
Trolley Wire, Lamp Cord

Send for Catalogue

United States Steel Products Co.
NEW YORK
Export Representatives

Wires and Cables

RUBBER INSULATED

NATIONAL ELECTRICAL CODE STANDARD

FOR

Submarine, Aerial, Underground and Interior Use

Write For Prices and Discounts

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Main Office, 125 CEDAR ST., New York

Factories, Stamford, Conn.

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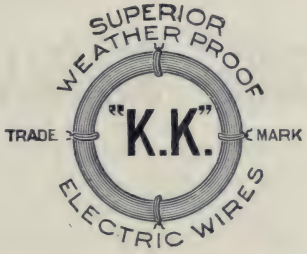
A. & C. B. Robinson, 503 Keller Bldg., Louisville, Ky.
B. F. Kierulff, Jr., & Co., 120 South Los Angeles St., Los Angeles, Cal.
Hand & Jones, 151 New Montgomery St., San Francisco, Cal.
Western Engineering Specialties Co., 1732 Glenarm St., Denver, Colo.
A. S. Doxsee, 1502 Chestnut St., St. Louis, Mo.
A. T. Egan, Felt Bldg., Salt Lake City, Utah.
Frank Haemar, Portland, Ore.
Northwestern Supply Co., 115 Prefontaine Place, Seattle, Wash.

WIRES & CABLES

"K.K." WEATHER PROOF WIRE & CABLE

BARE COPPER WIRE & CABLE



SLOW BURNING WEATHER PROOF

OFFICE, ANNUNCIATOR & MAGNET WIRES

HIGH TENSILE TROLLEY WIRE

WRITE FOR QUOTATIONS

BENEDICT & BURNHAM MFG. CO.

Successors to
THE HOLMES, BOOTH & HAYDENS CO.
WATERBURY, CONN.

BISHOP STANDARD

The New 1912 Code Wire

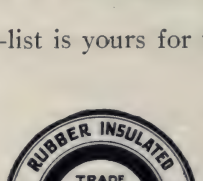
Meets all requirements of the revised rules of the National Electrical Code for Rubber Covered wire, effective January 1, 1912.

When you specify

BISHOP STANDARD

you can be absolutely certain that you will get the BEST OF THE NEW CODE WIRES. That you will get a product which is the result of sixty-three years' experience in the insulated wire and cable business.

Our new price-list is yours for the asking. Write for it to-day.



Specify Your Wire by Name
and be Sure of Results

BISHOP GUTTA-PERCHA CO.

428 East 25th Street

NEW YORK

THERE IS PROFITABLE SATISFACTION IN USING →

For Trolley (Catenary, Cross-span or Bracket construction) Telephone or Telegraph work.

Put up a section on the hardest spot in your line; watch it; make your own comparisons; then we think you'll agree that "Phono-Electric" is the most economical wire to use.

We want every man interested in Trolley, Telephone or Telegraph work to have a copy of our "Red Booklet." Mailed free. It gives facts—tells why *"Phono-Electric" is superior to Hard-Drawn Copper Wire.*

See table of comparative strengths on page 153 of this book.

Bridgeport Brass Company

Bridgeport, Conn.

WEATHERPROOF WIRE

A Product of 27 Years' Experience

NATIONAL CODE STANDARD

We also manufacture Slow Burning and Slow Burning Weatherproof Wires and Cables — Telephone, Telegraph and Signal Wires —Magnet—Office Annunciator and Enamel Wires— Bare Copper Wire and Strands—Rubber Covered Wire.

CHICAGO INSULATED WIRE & MFG. CO.

CHICAGO, ILL.

ESTABLISHED - 1885

Diamond

NEW

CODE

WIRE

Now Ready For Immediate Delivery

These new wires and cables meet all the physical, chemical and electrical specifications of the new 1911 code.

The life of rubber covered wires and cables depends upon their insulation.

Diamond wires and cables give longer and more efficient service because of their **superior insulation.**

Other Lines of Standard Diamond Quality:

Intermediate Grades
Diamond Special 30%
30% Para
Lead Encased Cables
Telephone Cables (braided)
Telephone Cables (leaded)
Igniter Cable

THE DIAMOND RUBBER CO.

Akron, Ohio.

DRIVER-HARRIS WIRE CO.

RESISTANCE ALLOYS

ROUND OR FLATTENED **WIRE** BARE OR INSULATED

"Nichrome"

For Electric Heaters

"Advance"

For Controllers, Arc Lamps

"Climax"

For Moving Picture Rheostats

"Therlo"

For Instruments and Shunts

Special Alloys for Special Applications

Armature Binding Wire

Hercules (TINNED STEEL) *Phosphor Bronze*

Heater Cords

DRIVER-HARRIS WIRE CO.

HARRISON, NEW JERSEY

BRANCH OFFICE AND STOCK

38 No. Clinton Street, - - - - - - Chicago

Every modern house is lighted with electricity.

The electricity is carried on Rubber Covered wires.

There are few, if any, things in a house so important as the insulation of this wire. If the insulation breaks down, the **least** trouble is the impossibility of securing light. What is more important is that a break-down may cause a disastrous fire with loss of property and life.

We have spent many years in studying the problem of making the ideal wire for the safe transmission of electricity in homes and buildings. We have experts who give this matter their constant attention.

We would like to have you consult us and make use of our experts in determining the wire best suited to your purpose. If this is not practicable because of time or distance, simply specify,

"The Electric Cable Company's Extra Tested 30% Para"

This insures your getting the best that money can buy.

It is not practical to make efficient tests outside the factory.
"Extra Tested" has a meaning—we want you to know what it is.

THE ELECTRIC CABLE CO.

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FOR ALL SERVICE

Wire

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Manufactured by

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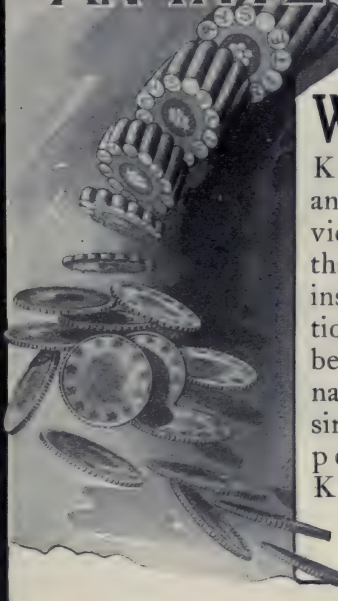

WHEN you put your money into KERITE you make an investment in service. You do more than buy conductors, insulation and protection. You obtain the best possible combination of the most desirable qualities in permanent form. KERITE remains long after the price is forgotten.

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The High Grade Insulation
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Massachusetts MAGNET WIRE

are well known

Made In
All Sizes

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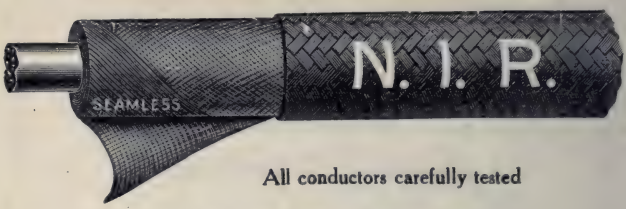

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HIGH GRADE SPECIAL CONDUCTORS
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is carefully drawn and annealed to produce a soft wire with a minimum variation in gauge, and is covered with a smooth and uniform insulation.

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Tested and Stamped by the Wire Inspection Bureau. Ask and Look for *One Green Thread* in the Braid to Identify

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SIGNAL WIRE **DROP WIRE**
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MEET EVERY REQUIREMENT

Prices and Quality Always Right

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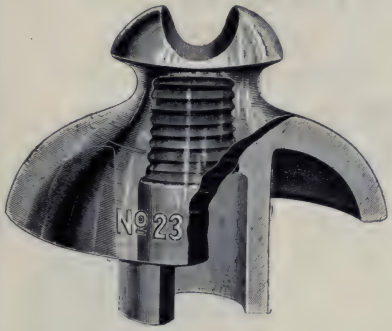

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THE STANDARD
FOR 45 YEARS

FOR LOW AND
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WITH OR WITHOUT
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WORKS: OLD BRIDGE, N. J.

EVERY STYLE
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SPECIAL
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CORRESPONDENCE
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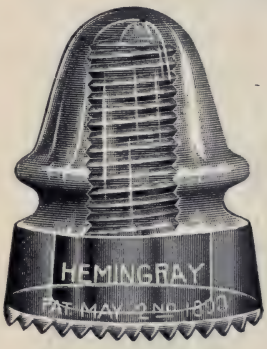
4000 Volts, Extra Deep Groove
Double Petticoat

See the TEATS on the PETTICOAT

They take all the moisture from the inner and outer surface of the insulator and keep the pin dry



Deep Groove
Double Petticoat

Cable

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Established 1848 Incorporated 1870

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Interior Conduits
Galvanite, American Wireduct

CONDUIT SIZES REQUIRED

Rubber Covered Double Braids	1 Wire	2 Wire	3 Wire
No. 14 B & S	½	½	¾
No. 12 B & S	½	¾	¾
No. 10 B & S	½	¾	1
No. 8 B & S	½	1	1
No. 6 B & S	¾	1	1¼
No. 5 B & S	¾	1¼	1¼
No. 4 B & S	¾	1¼	1½
No. 3 B & S	¾	1¼	1½
No. 2 B & S	¾	1½	2
No. 1 B & S	1	1½	2
No. 1-0	1	2	2
No. 2-0	1	2	2
No. 3-0	1¼	2	2½
No. 4-0	1¼	2	2½
200,000 c.m.	1¼	2	2½
250,000 c.m.	1½	2½	2½
300,000 c.m.	1½	2½	3
350,000 c.m.	1½	2½	3
400,000 c.m.	1½	3	3
450,000 c.m.	2	3	3½
500,000 c.m.	2	3	3½
550,000 c.m.	2	3½	4
600,000 c.m.	2	3½	4
700,000 c.m.	2	3½	4
750,000 c.m.	2	3½	4
800,000 c.m.	2	3½	4
850,000 c.m.	2½	4	4
900,000 c.m.	2½	4	4½
950,000 c.m.	2½	4	4½
1,000,000 c.m.	2½	4	4½

Rubber Covered Double Braids	1 Wire	2 Wire	3 Wire
1,100,000 c.m.	2½	4	5
1,200,000 c.m.	2½	4	5
1,300,000 c.m.	2½	4½	5
1,400,000 c.m.	3	4½	6
1,500,000 c.m.	3	5	6
1,600,000 c.m.	3	5	6
1,700,000 c.m.	3	5	6
1,800,000 c.m.	3	6	7
1,900,000 c.m.	3	6	7
2,000,000 c.m.	3	6	7

Miscellaneous.

1 No. 10 & 2 No. 14			¾
1 No. 8 & 2 No. 12			1
1 No. 6 & 2 No. 10			1
1 No. 4 & 2 No. 8			1¼
1 No. 3 & 2 No. 6			1¼
1 No. 2 & 2 No. 6			1¼
1 No. 1 & 2 No. 5			1½
1 No. 1-0 & 2 No. 4			1½
1 No. 2-0 & 2 No. 3			1½
1 No. 3-0 & 2 No. 2			2
1 No. 4-0 & 2 No. 1			2

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A perfect, non-metallic flexible conduit, Spiral fiber, inner tube, a real rubber tape and a perfect outer cotton jacket with the kind of compound that lasts.

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You get every inch you order, and it's all guaranted.

Ask your jobber, or write us direct for discounts.

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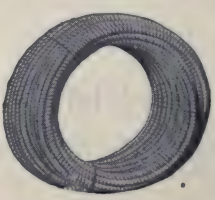

CONDUIT WORK

MODERN construction makes essential the use of an armor or metal protection to electric wires; mechanical injury during construction or after completion of the work causes such annoyance, expense and damage, that the first cost of a conduit system over knob and tube work, exposed wiring, molding or non-metallic tubing construction is now considered of no consequence when safety by metallic conduit protection is secured.

FIRST IN PROTECTIVE QUALITIES IS

"Galvaduct"
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(All Patented)

THEY ARE THE BEST

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GROUND CONNECTION CLAMPS

For Rigid and Flexible Conduit
National Electrical Code Standard

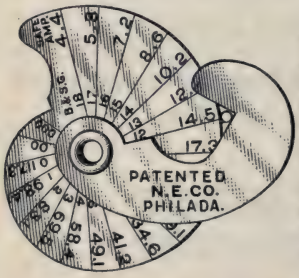
Made of one piece of copper insuring perfect and permanent contact
Made for all Standard sizes of rigid and flexible metallic conduit.

Patented

Write for NEW PRICES which will be of interest

Pat. Pending

"NECO" Wire Gauge



Our IMPROVED "NECO" POCKET WIRE GAUGE, for measuring wire from No. 18 to No. 000 B. & S. gauge. On the front is also given the carrying capacity of copper wire in amperes and on the reverse side the approx. decimal equivalent of the various size wires.

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Friction Tape
- Guaranteed Durability
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Splicing Compound (Pure Rubber Tape)
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- Perfect Joint without Heat

For mending Insulation on Wire and all High Tension Work

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MOULDING VARNISH

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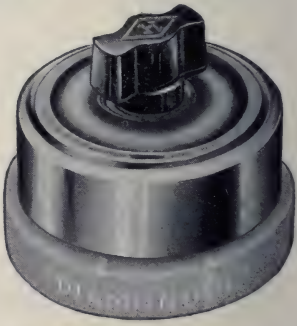

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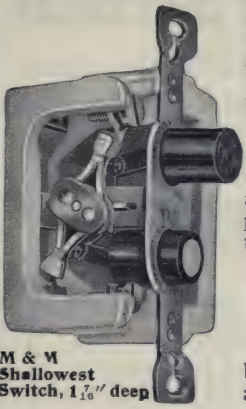

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and are always on the lookout for improved fittings that will give the greatest satisfaction to your customers and at the same time make you the most money.

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are increasing the business and the profits of thousands of contractors—they will increase yours.

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Switches superior in mechanical and electrical features, such as sturdy porcelain covers—corners will not chip.
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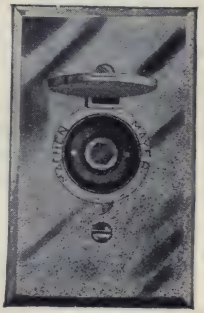

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The Ideal Mill Switch

30 Amp., 250 Volt,
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must successfully combat extreme conditions and the roughest kind of handling.

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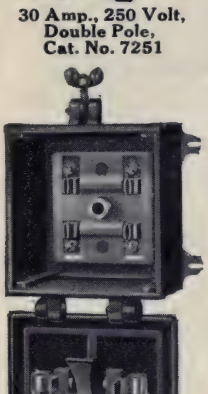
not only make good on mill work, either motor or lighting circuits, but repeatedly save their cost by preventing accidents and shut downs. They are a permanent investment, eliminating the fire hazard, and are also recommended for mines, railroads, packing houses, laboratories, or any place where a "Foolproof, Fire-proof, Fumeproof" switch is necessary.



Switch open, showing spring mechanism

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Large Sized Switches a Specialty.

Panel Boards, Switch Boards and Cabinets

Comb. Switches, Panel Cutouts, Plug Cutouts, Slate Base and Porcelain Fuse Blocks, Rosettes, Iron Service Boxes, Ironclad Switches, Battery Switches, Porcelain Base "B" Switches, Flush and Conduit Receptacles. W. P. Sockets, Panel Parts, Wire Connectors, Attachment Plugs, Moulding Branch Blocks, Moulding Receptacles, etc., etc., etc.

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Insulated with Pure Asbestos

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ENCLOSED FUSES & BLOCKS

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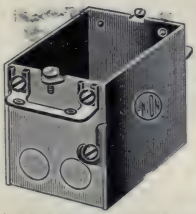
Made in accordance with **Underwriters' Specifications** and carried on the List of Approved Fittings.



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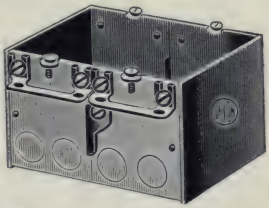
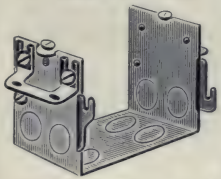
Sectional Switch Boxes
Patented Apr. 2, 1907
Equipped with Reversible and Sliding Ears for Old and New work



"C C" 2 Gang



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Takes all makes of Switches and Receptacles made in depths from 2 inches to 3½ inches.

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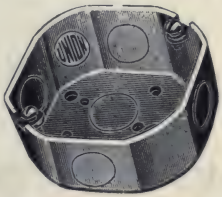
The most complete line now on the market
A Box and Cover for every requirement



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EASY TO INSTALL EASY TO TAKE DOWN

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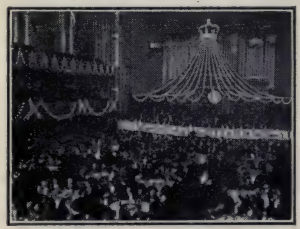

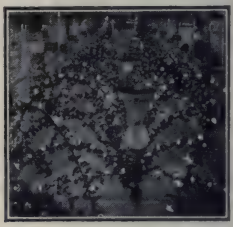

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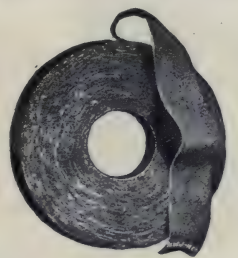

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Prove to yourself that we succeed in doing this by testing LUCEO under conditions of actual use. Because the entire surface is diffusive LUCEO presents a soft and pleasing appearance—a rich warm glow—and yet at the same time the light is scientifically distributed as proved by distribution curves made by the National Testing Laboratories. LUCEO gives you the benefit of *all* the light on account of its remarkably low co-efficient of absorption. We want you to feel the same satisfaction experienced by dealers who are now handling LUCEO and therefore ask you not to delay writing us. We will send you data that will fully inform you of the merits of this newer, better, handsomer ware. Prices will merit your consideration.

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There are no other inner or outer arc lamp globes, or tungsten reflectors, or gas and electric fixture globes that give as much satisfaction and pleasing service as do "Phoenix Quality."

Use "Pheno" Tungsten Reflectors for the most beautiful soft light giving the strongest illumination.

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REFLECTORS

EFFICIENCY
ARTISTIC EFFECT
SCIENCE *and*
DISTINCTIVENESS

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are embodied in Haskins-Lucida reflectors, spheres and hemispheres. Lenticular reflectors for high efficiency are acknowledged the best. In addition to the scientific lines of reflectors, namely, Haskins-Lucida and Lenticular we make a complete line of illuminating glassware in cut, etched, roughed inside, etc., etc.

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Our New **"HIGHLAND"** *Line of*

ELECTRIC AND COMBINATION FIXTURES

The same methods as used in the manufacture of our portables are adopted in these fixtures and when shipped they will be mechanically correct, plumb and square.

These fixtures are winners and prices low. Line includes fixtures of all kinds, Tungsten fixtures, showers and brackets.

Write for illustrations and mention "Highland" Line

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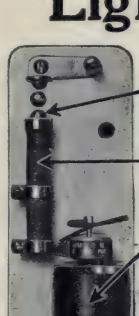
WINSTED, CONN.

THE
Only Circuit-Breaker
Lightning Arrester



Small Air Gap

Low Resistance

The Circuit-Breaker

It is the circuit-breaker used in combination with a small air gap and a low series resistance that has given

Garton-Daniels Lightning Arresters

their well known characteristics of efficiency, reliability and durability.

It's small air gap distance and low series resistance that make them *efficient*, affording an easy path from line to ground for any static or lightning.

It's the circuit-breaker that makes them *reliable;* with this positive means for cutting off the flow of line current following a discharge to earth, grounds and short-circuits due to lightning are practically unknown.

And the proof that they are *durable* is found in the absolute satisfaction they give and are giving wherever used.

Garton-Daniels Arresters are made for voltages up to 1300 D. C. and up to 20,000 A. C., and are sold by jobbers generally throughout the United States, and the Dominion of Canada.

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The U. S. Govt. has adopted the "megger-method" for testing insulated wires and cables; and prominent supervising and operating engineers are using it.

All wiring-jobs should be tested with a megger, when new—and all old installations should be tested periodically, to determine whether they are safe fire-risks.

Full particulars as to Meggers-and-what-they-will-do are given in our *illustrated catalogue 737.* Every Wiring-Contractor and every Electrical Engineer should have a copy. *Mailed free upon request.*

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Electrical Measuring Instruments

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A Full Line of
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Indicating Instruments

Is Offered by this Company, comprising

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Portable Type

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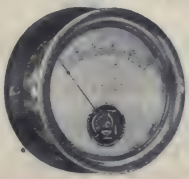

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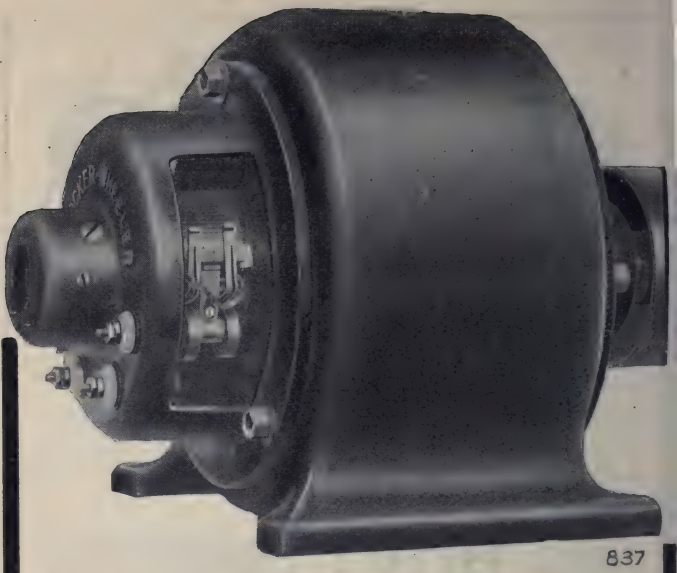

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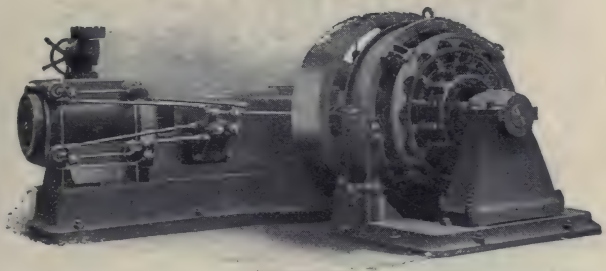

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Because of their quiet operation, reliability, close regulation, ease of maintenance and repair they are splendidly adapted to the requirements of office buildings, hotels and any light and power installation where satisfactory and efficient service is desired.

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Our generators are highly efficient and sparkless at all loads.

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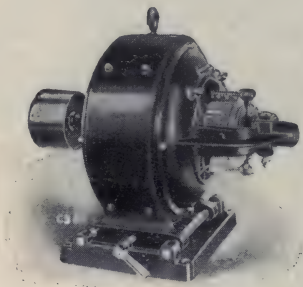

The "Standard" Power Motors are made in an exceptionally comprehensive variety of frames, for all kinds of work, for all direct current circuits and in sizes up to and including 20 H. P. This line comprises motors of the open, gauze enclosed or solid enclosed style. They are also supplied on special order for vertical operation, back geared, variable speed, with interpoles, with or without the popular round rod style of sliding base which is a distinctive feature of this line of machines. In short the "Standard" Motors are universally adaptable to any possible requirement for small motor application.

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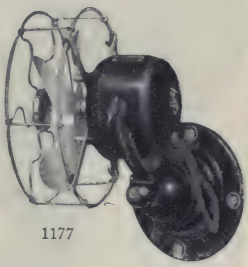
All popular sizes and styles as well as distinctive types for special conditions. Very quiet types for residences and hotel bedrooms.



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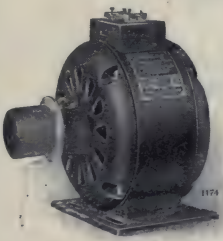
For all Light Power Purposes



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ABSOLUTELY NO SPARKING
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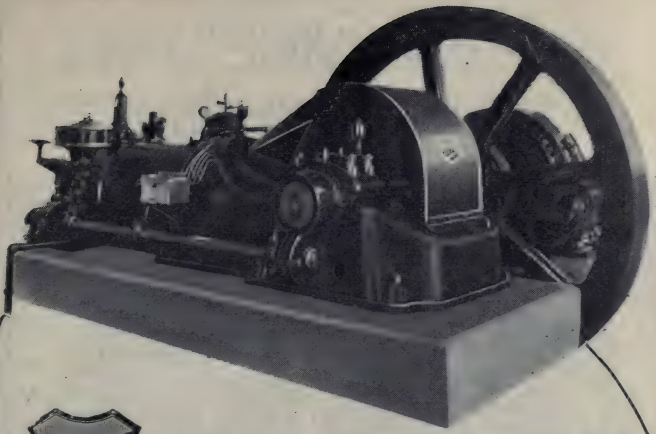

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produce electric current at a lower cost than by steam and cheaper than other makes of internal combustion engines.

They are world renowned for fuel economy and low cost of up-keep.

Our throttling governor and special electric types operate with such close regulations that we guarantee that the regularity of the engine will be such that the variation in voltage will not exceed 2 per cent. under changing load from one-third to full load.

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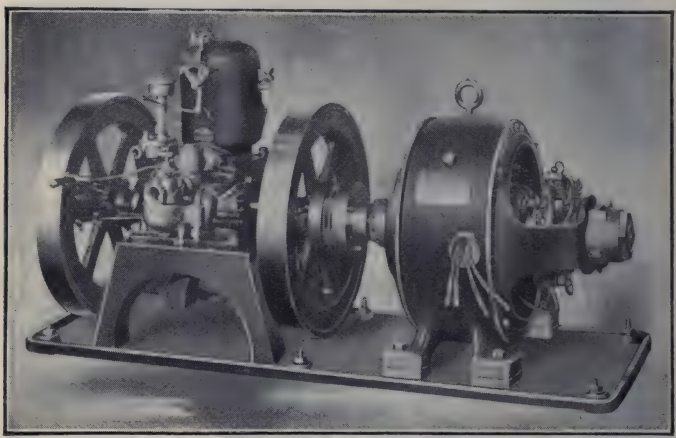

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Just the thing for { Moving Picture Shows, Country Residences, Yachts, Etc.

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2-3-4 and 6 K. W. sizes. 60 volts to 160 volts

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Time Piece is a strong, reliable 8-day Pendulum movement. Time-Switch 2-way, 8-day, quick make and break. Cases handsomely finished in Oak, Mahogany or Walnut. Is an ornament and accurate Time Piece. Thoroughly inspected and tested before shipped.

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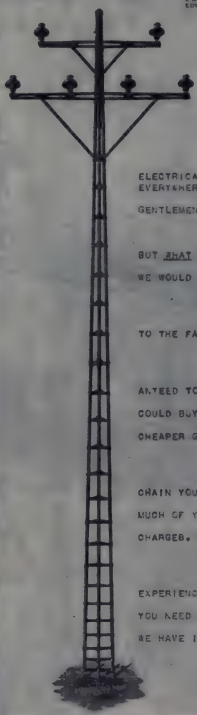

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EVERYWHERE.

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VERY TRULY YOURS,

THE FRANKLIN STEEL COMPANY.

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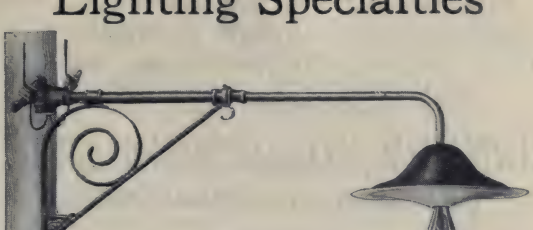
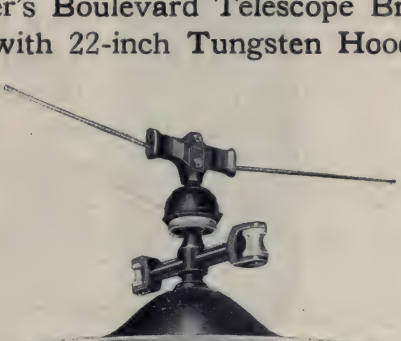


Cutter's Boulevard Telescope Bracket
with 22-inch Tungsten Hood



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Will Not Corrode

Especially adapted for all kinds of **ELECTRICAL WORK**

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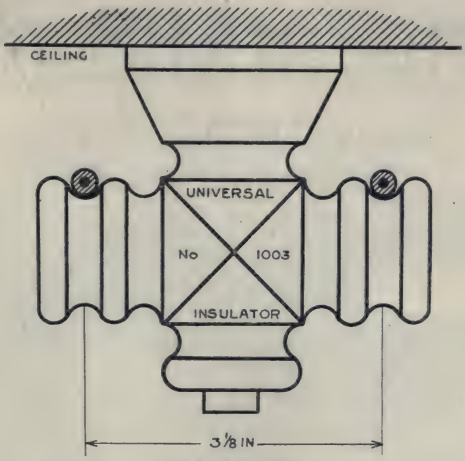

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HIGH INSULATION assured, even in damp places, by the corrugated porcelain surfaces between the wires, ceiling and lag screw.

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UNIVERSAL INSULATOR No. 1003 offers a novel form of construction intermediate between knob and bracket work.

Thousands in use in stockyards, breweries, factories, etc.

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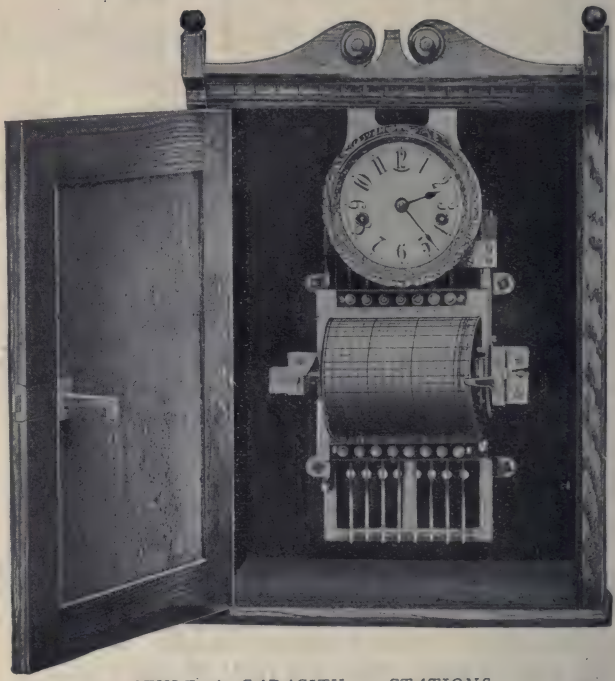
APPROVED BY UNDERWRITERS



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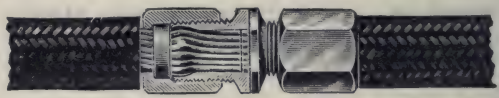
Dossert Solderless Connectors

2-Way Type A, Showing Details

Dossert Connectors eliminate entirely the use of solder in making electrical connections and splices, and are approved for use without solder by the National Board of Fire Underwriters for all classes of wiring.

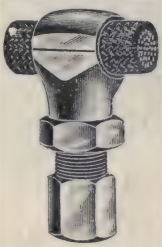
By their use much labor is saved and splices obtained that will withstand any overload. Many careful tests show that a splice made by means of a Dossert Connector will not heat as much as the cable which it connects when the cable is heavily overloaded.

Type A Connectors are for use on cables, stranded or solid wires, rods and tubing. They are simple and effective, and by their use splices can be quickly made in conductors of any size. Type A Connectors however, should not be used on a cable that is to be subjected to heavy tensile strains.



Part Cross-sectional View of Type B 2-Way

Type B Connectors are for use on stranded wires or cables only, and are designed to make a joint which will withstand heavy tensile strains. They are not made for wires smaller than No. 0.



Cable Tap

The Cable Tap is used to connect a branch wire, rod, or bleeder, to a main wire, rod or feeder. It does not splice the main, but simply clamps on to it. Branch wire is connected to cable tap by means of a nut and sleeve as shown in cut.

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You need it as much
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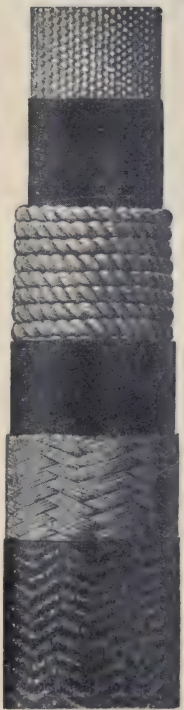
Easiest to "Fish."

Try it and prove it.

THE HIGHEST ACHIEVEMENT IN THE ART OF INTERIOR CONDUIT CONSTRUCTION



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← Hard fibre cord.

← All intersects filled with special compound.

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← Outer coating. protection against dampness and abrasion.

→ Finished Conduit.

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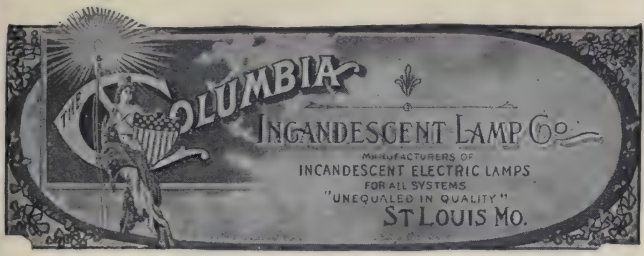

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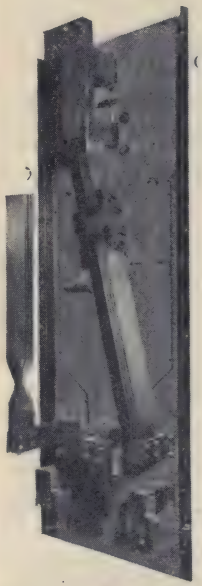

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6000
AMPERE
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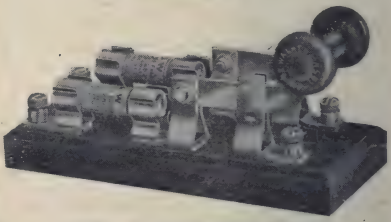
SWITCH
CONTACT



TYPE "C" PANEL BOARD SWITCH

WALKER ELECTRIC COMPANY

Nobel & 24th Sts., PHILADELPHIA

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CHICAGO, Monadnock Block BOSTON, 84 State St.
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for every service, alternating and direct current from 125 volts up.

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Switches

of all kinds and sizes—knife with laminated and round studs—instrument switches with laminated contacts, etc.

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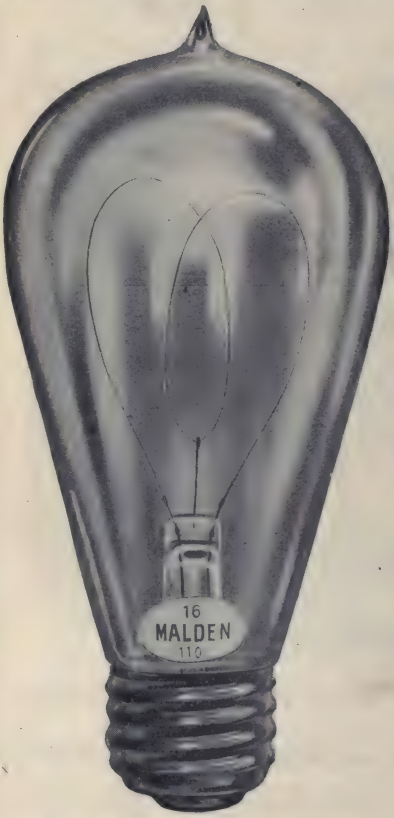
and SAVE 6 or 7 CENTS on EVERY LAMP you use



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AND

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